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THE RELATIVE STABILITY OF INDIAN VEGETATIONAL TYPES

BY

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(Presidential address delivered at the eighteenth annual meeting of the Indian Botanical Society at Lahore, on 7th January 1939.)

I. INTRODUCTORY

To the casual observer, most of the familiar types of vegetation seem to retain their general appearance and composition over long periods of time; what he remembers from his childhood as open thorny scrub (1) 8 to 15 ft. high, perhaps with here and there a grove of mangoes, still looks the same when he reaches manhood and even old age; and similarly for the open grassy plain, the sandy river bed with grassy tussocks, and the closed forest on hill and plain.

If his attention is drawn to the matter, the older man will quite probably tell you that there was tree forest in his youth supplying all local needs for timber, tools and fuel, where now you see only open thorny scrub; but sometimes, on the contrary, he will tell you that a certain tree jungle was only a stony gravel bank or open grass land in his youth. The close observer of such changes—we now term him a plant ecologist—quickly realises that, except in unfrequented parts of the country, change, not stability, is the order of the day for the vegetation occupying the soil. The old villager remembers only the outstanding instances, but the ecologist finds that it is exceptional in India to

find areas which do not yield evidence direct or indirect of having changed considerably from a former condition and of being likely to change further in the future. The tempo of these changes varies within very wide limits, being as a rule faster the more recently and intensely human influences have impinged on the area considered.

II. EXISTING VEGETATIONAL TYPES

India has a wide range of vegetational types corresponding with its exceptionally wide range of climatic conditions, from the edges of the eternal snow to the hot constantly moist forests of the Western Ghats and the hot continuously dry desert vegetation of Sind and Rajputana; also to the wide variation in soil from loose dry sand to stiff clays, laterite, black cotton soil, and the dark humus soils of the temperate hill ranges. A survey of the forest and shrub types of India and Burma was published in 1936 (2) and studies have been published, several of them in the Society's Journal, of non-forest types such as the low desert vegetation (3), lake side herbaceous (4), (5), (6) and aquatic floras, etc. In my presidential address to the Botanical Section of the Indian Science Congress in 1937 (7), I developed the thesis that forest was what is known as the climax vegetation (8), (9) over almost the whole of the country, with only relatively minor exceptions notably in the dry eastern areas and the tops of the Himalaya above timber line, and this view appears to be shared by the majority of writers on the subject.

For the purposes of this address, we need make only the simplest sub-division of the vegetative cover as we find it into:

(1) grassland,

(2) savannah forest (i.e., open woody cover with herb vegetation between),

(3) Scrub,

(4) Deciduous forests,

(5) Evergreen forests, and

though references may be made to aquatic vegetation, cultivated crops, the special vegetation of our estuaries, etc. It is proposed to consider representative occurrences falling into each of these sub-divisions from the point of view of their past history, known or deduced, the factors affecting their present apparent stability, and finally their probable future.

III. EVIDENCE OF CHANGE

It is necessary first to consider briefly in what direction evidence of past history may be available if looked for. Firstly, there may be written records as in the well-known instance of the hunting exploits of the Moghal Emperors in Etawah district; here the level tree forest with local heavy grass, then frequented by rhino, etc., has in 2-3 centuries become tortuous ravine land with thorn scrub and only poor thin grass.

Secondly, we frequently have direct archaeological evidence of which perhaps the best example personally known to me is just outside India in what is known as the Dry Zone of Ceylon, now under almost unbroken forest over hundreds of square miles, but 1,000 years ago supporting a great population, the ruins of whose cities and irrigation works are scattered throughout.

Less obvious evidence of a similar type is supplied in nearly all our hill tracts by traces of ancient terracing of the slopes, proving they have once been completely cleared and cultivated.

Again, the vegetation itself may provide useful evidence of changes which must have occurred or at least influences which must have been at work during the last century or so. A common clue is the presence in a forest area of a patch of growth of varying extent, usually on good soil or a warm slope, and near water, differing from the surrounding growth in specific composition and form, and characterised by the presence of big branchy shade or fruit trees such as mango, mahua and tamarind and often exceptionally large and branchy specimens of the jungle trees, also proving as definitely as any written record that here is the site of an old clearing and settlement with the manifold influences which man and his grazing herds formerly exerted in this spot and its vicinity.

Often associated with the type of evidence just mentioned but still less obvious to the layman and very liable to be overlooked by the botanist who is not also a forester, is evidence supplied by the average age and uniformity of the tree crop an area carries. A forest devoid of scattered trees which have reached the natural span of life of the constituent species cannot be in equilibrium with the habitat, and influences must have been at work accounting for their absence. As an example of this, (10), I may quote an apparently stable pine forest in Kumaun well covered with trees of all sizes except the biggest which other similar sites normally carry. Age studies showed that these trees despite their range in girth from 3′ to 6′ were all of very much the same age, 100—120 years (the natural term of life is over 200) and on closer examination traces of partial terracing were discernable here and there. It can hardly be doubted that the whole slope had once been cleared of trees for the shifting cultivation previously practised; further support for the deduction was available in the general historical records of the tract which shew that it formerly carried a relatively dense population.

This general type of evidence has to be accepted cautiously or the student finds himself begging the question he has set himself. The extensive hill tracts between Bengal, Assam and Burma offer a most interesting ecological problem in this way. Vast areas now carry a dense growth of bamboo (primarily *muli* or *Melocanna bambusoides*) with scattered trees of species mostly found in the wet tropical evergreen forest such as

Dipterocarpus alatus, Mangifera longipes, Amoora, etc. Clearings for shifting cultivation are known to become covered in time by this bamboo and to leave scattered trees of the original forest, and the natural deduction would be that the type has originated over whole area in this way, but much further evidence is necessary before this hypothesis can be considered as proved.

The example just quoted also provides an instance of another type of evidence to be considered, i.e., indications in the composition of the vegetation itself that it differs for no reasons apparent in the site and soil, from the type which is associated with such soil and site elsewhere. Thus, the soil and site in our example are often such as elsewhere carry closed evergreen forest including the species of which isolated examples are found standing over the bamboos or on steep slopes and in sheltered ravines. Such an area should, one deduces, also carry closed evergreen forest, surely must have done so in the past, and perhaps may yet do so again in the future if restraining influences are kept away or removed.

Other instances are provided by the predominance of thorny and inedible species in almost all the remaining woodland of our thickly populated districts, and by the predominance of the hardiest species (especially gregarious ones like *Shorea robusta*) in the more extensive forest areas. I have previously quoted (10) a striking example of this from the W. Himalaya, where a single spur rising from a river at 2,500 ft. to about 6,500 ft. carried residual forest at three levels; it had at the bottom almost pure stunted *sal* forest with a little thorny undergrowth of *Carissa, Randia,* etc.; then after a break a pure *chir* pine forest with no undergrowth whatever; and finally at the top pure oak. The oak is very hardy to lopping and had a mixture of *Rhododendron* and *Pieris* which was in far higher proportion in the opener fringe, than in the better stocked forest further from human habitation, these species being inedible to cattle and of poor fuel value.

The evidence so far considered has dealt with past changes; there may also be evidence of changes to come. One example from the plains and one from the hills will suffice. Many old woods of *sissu* (*Dalbergia Sissoo*) will be found to have no young *sissu* on the ground but a copious supply of *Holoptelea* which will replace the *sissu* as it dies out from old age. Similarly examples are common of a maturing blue pine wood with ample regeneration of silver fir but no young blue pine.

IV. AGENCIES OF CHANGE

We will next review the chief agencies at work on the vegetation likely to affect its stability and bring about changes, dealing firstly with injurious agencies and the opposite effects of removing or restricting them, and then with the results of intelligent human endeavour. Most of these agencies have been mentioned

already. To them must be added the natural changes taking place in new or disturbed soils with the passage of time.

1. **Clearing for cultivation.** This in India normally means the destruction of woody growth of some sort and its replacement by cultivated, usually herbaceous crops. Occasionally grassland is similarly treated.

2. **Clearing round cultivation and settlements** by removal of building material and fuel, sometimes with intentional destruction of trees to improve grazing or to keep away wild animals; burning and lopping for fodder are important contributory factors. The results vary with the original vegetative type, but the general effect is degradation of high forest to savannah types with open tree cover and herbaceous or shrubby undergrowth, the latter with the weeds of cultivation and waste places prominent. Where cattle are herded, nitrophilous vegetation becomes conspicuous. The trees tend to become limited in time to a few species, either useless ones or favoured fruit and shade trees. Invasion of introduced weed species frequently follows, *Lantana* and *Eupatorium* being outstanding examples which have so altered conditions that we cannot yet say what the ultimate outcome will be.

3. **Grazing.** All original vegetation is of course subject to the grazing and browsing of the wild animals naturally associated with the site, but on available evidence though this influences in some degree the proportions of the several component species, it does not affect the general type or form of vegetative cover. The grazing of domestic herds on the other hand is a totally different matter in that the intensity factor is increased beyond all proportion to the stock of wild animals they displace, and with fire constitutes the most influential agency now affecting the vegetation. Such heavy grazing in a forest usually affects it mostly through its deterrent action on the regeneration of the tree species; by trampling and exposure of the soil, conditions are rendered more difficult for the seedlings and such as survive are exposed to being eaten by the cattle, only some species being adequately protected by non-palatability. The intensity factor is important, for a light degree of grazing by reducing the undergrowth and exposing the mineral soil may actually facilitate the establishment of tree seedlings especially where there has been much accumulation of raw humus as in our fir forests. It will be noted, however, that in both cases the natural course of events will be altered by the introduction of the domestic grazing factor.

Considering herbaceous growth, grazing again exerts a very far-reaching influence, varying much with vegetative type and locality and grazing intensity. Inedible species are always favoured, e.g., *Cassia spp.*, *Asclepiadaceæ*, etc., as also are thorny ones, e.g., *Mimosa*, *Zizyphus*, etc., and ground lost by the more

edible herbs and grasses. On the other hand, grazing of grassland on old cultivation, etc., frequently prevents or delays its occupation by the coarse tall grasses.

The kind of cattle grazing is also very influential, the browsers, goats, buffaloes and to a less degree sheep, checking woody growth far more than cows and horses. Heavy grazing by browsers may turn dense high forest into grassland or scrub in a tree generation by inhibiting tree regeneration whilst the old crop slowly dies out; this is visible throughout the fir forests of the Himalaya.

The direct results of grazing are accentuated by the activities of the accompanying graziers who lop the fodder trees for their flocks and herds, encourage the extension of grassland by burning and girdling and meeting their own needs for building material and fuel.

4. **Burning.** Much has been written, mainly by foresters, of the effects of burning on the natural vegetation of the country, and it cannot be repeated here. The general effect is to degrade the vegetation to a form typical of a drier climate than is indicated by the meteorological records, thus moist evergreen forest is degraded to deciduous forest or grassland, deciduous forest to savannah, and moist coniferous forest to scrub or grass. Where the general facies is not much altered, the species composition is altered in favour of the fire hardy species; thus in the Gangetic plain, we hardly know what the natural forest was like before it was affected by human influences including burning, but there is ample evidence that most of the forests which are now almost pure *Shorea*, must have been much more mixed, with *Shorea* rare or even absent in many places. Again the present monsoon savannah type forests contain little except the most fire hardy species such as *Lagerstroemia parviflora Sterculia villosa, Bombax*, etc., though there are plenty of others now limited to favourable moister spots which could grow equally well with them if it were not for the periodic fires associated with human settlement.

5. **Abandonment of cultivation.** The succession of vegetation which occupies abandoned arable land provides one of the most conspicuous examples of ecological changes and all of us must have personal knowledge of several examples. Factors to be kept in mind are the duration and intensity of the cultivation which determine the extent of survival of remnants of the original vegetation, the surrounding vegetation which controls the relative ease of colonisation of the vacant site, and the incidence of grazing and burning. Long continued cultivation of land formerly under forest is liable to alter the soil both physically and biologically so radically that reoccupation by forest may be extremely slow. Instances could be quoted of old fields in the

middle of a forest which after 50 years or more still appear much as they must have done a few years after they were abandoned. However, more generally, grasses and other herbaceous vegetation quickly occupy the ground ; shrubs and trees, especially those with effective seed dispersal mechanisms soon follow, particularly on old banks or bunds. Further development is too varied to discuss here, but in a general way, if restraining influences are light or moderate, there is a slow progression to the vegetational form appropriate to the climate and soil as indicated by undisturbed areas in the locality, and a still slower progression to the same specific composition. If the restraining influences are more effective, the progression continues to some stage short of this, and then appears to become stabilised as what is termed a subclimax.

6. **Stoppage of intensive grazing.** In any heavily grazed area where grazing has been excluded or considerably reduced, marked changes soon become apparent in the ground vegetation, often very quickly if conditions are at all favourable. There may be a marked increase of the more delicate edible grasses and herbs, but this may be followed by their displacement by the coarser perennial species (and so deterioration as grazing land). After this, progression usually takes place much as described in the preceding section towards the climax vegetation of the locality. Where the grazing ground was degraded forest, protection will have some of the effects just described, and may lead to copious regeneration of tree species re-establishing a closed tree crop which will bear for a century or more the signs of its past history.

7. **Fire protection.** It is only in the last decade or so that the far reaching effects of excluding fire have been realised, just as the great influence which burning has had on our vegetation was also not adequately grasped. Grassland is still mostly burnt annually, partly in the belief that it improves the species composition, but mainly to induce an early flush of edible new growth in the lean months from March to June. Burning grassland tends to check or inhibit tree growth, and so protection usually results in its development, e.g., *Macaranga* in the North Bengal *sal* tract. Burning in deciduous forests prevents or checks the development of all fire-tender species, and almost all evergreens are fire-tender ; protection accordingly results in the closing up of the forest with a greater variety of species and in the addition of a proportion of evergreens varying with the climate and site and other factors. Fire protection of most types of scrub growth results in their progression to tree forest, e.g., temperate montane scrub to *Pinus excelsa.*

8. **Human control.** Our object in striving after an understanding of these changes is two fold, viz.,

(1) the purely scientific thirst for knowledge and understanding of ultimate causes and

(2) the application of the knowledge gained to the control of our environment to make it conform to our wishes.

Much long established agricultural practice is of course the application to the control of vegetation of experience gained by long experience and much trial and error experiment. The proper management of Indian grassland and grazing to which so much attention has been drawn of late, is a big field which is calling most urgently for a large force of scientists. I leave this aspect of my subject to those more competent to describe it. The introduction of systematic forest protection and management some 70 years ago has given results in all parts of this country which are full of interest and importance to the student of ecology. The countless instances where forest growth has since been completely destroyed right up to the legal boundaries then laid down, so that the protected forest is mistaken for an artificial plantation, may first be cited as a conspicuous feature. Within the forest the most important changes have resulted from protection against uncontrolled felling, from fire protection and from limitation or local exclusion of grazing. Again only one or two instances can be quoted. There are many examples also where inferior scrub has now developed with protection to valuable productive forest. In Bengal and Assam, a dense evergreen undergrowth, which has developed in *sal* forests, has completely inhibited the natural regeneration of the *sal*; *sal* however is by far the most valuable timber tree, so that to maintain it and get up a new crop of *sal*, special measures have to be taken, to replace the evergreen undergrowth by a light grass growth, by cutting and burning. Ecologically speaking, a climax forest of unknown composition but evidently largely evergreen and probably with only local patches of *sal* on suitable sites has in the past been converted by human agency probably through grassland and savannah into a nearly pure *sal* sub-climax type which would progress again towards the climax with continued fire protection, but for timber production purposes has to be brought back to and maintained at the *sal* fire sub-climax. Just as the selective destruction of useful constituents of a mixed vegetation has been a marked feature in the past, so the selective protection and extension of desirable species is an important objective of intelligent management, and is gradually bringing about far-reaching changes in our woodlands, and in similar ways it is to be anticipated it will do the same in our managed grasslands and mixed grazing areas. The opinion has been expressed (11) that "India has no natural grassland area", whereas it seems quite likely that an increasing area will have to be maintained by artificial control of other vegetational types.

V. CHANGES IN PROGRESS IN DIFFERENT TYPES

1. Grassland

(*a*) *New riverain grass of North India.* *Saccharum spontaneum* is the characteristic species and may be maintained for some length of time by flooding with redeposition of sand by burning and grazing. In time however it very usually progresses to the *khair-sissu* and *Populus-Tamarix* types of forest. As a type it is always being reproduced in suitable localities, but on a given area is shortlived.

(*b*) *Older riverain grass of North India.* Grassland of various types is typical of the more stable lower alluvium. The grasses are mostly tall and coarse but provide valuable grazing from new growth after burning. The wetter sites often remain under grasses such as *Phragmites Karka* and *Saccharum procerum*, etc., until silt deposition raises and dries them but the drier and higher sites are slowly colonised by tree growth, fire hardiness and often frost hardiness being essential to success. Fire protection results in increase in the tree growth and it is evident that the grassland would soon progress to monsoon forest as the next stage. The higher old alluvium also carries a great deal of grassland again of tall coarse grasses such as *Anthistiria gigantea*, *Erianthus spp.*, etc., with *Imperata* (12). The results of protection indicate that much of this is also fire conditioned while other parts appear to be old clearings and will progress to monsoon forest notably *sal* forest (13).

(*c*) *Temperate grasslands of South India Hills.* Ranganathan (5) and Bor (6) have recently written on this type the former holding it to be a stable true climax, and the latter believing it to have been mostly preceded by the evergreen forest now limited to the sholas persisting only on favourable sites; I had previously (7) upheld the latter view.

(*d*) *Alpine grasslands.* Detailed studies are wanting but this may well be a true climatic climax.

2. Savannah types

(*a*) The riverain savannahs have been mentioned with the evidence that whilst they may frequently be a natural stage in the primary succession from river deposit to closed forest; they tend to be maintained as such by fire and grazing.

(*b*) Deciduous savannah forest is met with all over the hills and plateaux of Central India especially in the rather drier tracts and sites. In many parts progression to closed forest can undoubtedly take place with protection but other parts may well be viewed as the climax type.

(*c*) *Thorn savannah,* May be taken to cover much of the open forest of the Punjab *rakhs* and the open dry *Acacia* forests of the older alluvium and Central India. Evidence can be found indicating that much of the latter owes its existence to the degradation under human influences (14) from the drier variations of the deciduous monsoon forest but the Punjab semi-desert type though anything but free of human influences, is not far removed from the climax type. How rapidly the *rakhs* are disappearing is known to every resident in and visitor to the Punjab.

3. Deciduous forests

The summer deciduous monsoon forest is perhaps the most characteristic in India. It includes the *sal* and teak bearing forests occupying most of the remaining forest area and has provided most of the examples already quoted above of change and human influences. It is indisputable in many places that it has displaced evergreen forest and abrupt changes are constantly met with which are definitely not traceable to changes in rock or soil. Owing to the sensitiveness of evergreen seedlings to exposure and still more to fire, and probably to the soil changes which have taken place, the return of the evergreen is usually a very slow process and the deciduous type appears very stable. At the same time, though composition may be different, the general form of the deciduous forest is probably the true climax vegetation of a great part of the country.

The *khair-sissu* forests of new riverain soil have already been mentioned and provide one of the best available examples of a type which is always only a phase (sere) in vegetational history. It never regenerates itself on the same site but provides shelter for the establishment of a new stage on the way to the typical monsoon forest, a phase characterised by such trees as *Holoptelea, Albizzia, Bombax* and *Adina.* In drier climates, the poplar—*tamarisk* forest gradually changes to the thorn forest of the upper Indus basin. Soil changes are obviously closely associated.

The status of our rather limited temperate winter deciduous forest is less clear, but it is certainly frequently succeeded by coniferous forest or evergreen oak. Elsewhere it seems to be stable and conditioned by soil and moisture conditions.

4. Shrub types

Except for desert scrub and alpine scrub (notably *Rhododendron* spp.) all the main scrub types met with appear to be quite definitely ascribable to degradation types from high forest, or several stages in primary or secondary succession. Examples are the shrubby growth of *Wendlandia, Melastomaceæ,* etc., of the south, *Dodonæa Woodfordia, Adhatoda,* etc., of the north, *Indigofera, Spiræa,* etc., of the temperate hills, and the dwarf mangrove of our deltas.

5. Evergreen forest

The moist tropical evergreen forest appears to be the climax type wherever the annual rainfall exceeds 80" and the dry season is not prolonged (2). If this is correct it must once have occupied a much larger area than it does now, even allowing for its possible absence on unfavourable soil types (15). Mention must be made of our tidal forests as these are so obviously changing as the land is raised higher and higher by deposition of silt, and by the varying salinity of the water submerging them. Our coniferous forests as a whole are decidedly stable though examples of the fluctuating equilibrium with broadleaved forest and between the several species of conifer have been mentioned.

In conclusion, a few remarks are called for on the nature of the climax vegetation to which repeated references have been unavoidable, the end stage to which all existing vegetation is presumed to be progressing for the first (primary succession) or subsequent (secondary) time. Still the most widespread view is that developed by Clements (8) that for a given climate both vegetation and soil tend to develop to a single climax form whatever the initial differences; the climax vegetation is not expected to be absolutely uniform as there will always remain local factors opposing the climatic ones checking attainment of the climax (giving us a preclimax) or permitting over-stepping to a more advanced stage (a postclimax). Other workers find themselves unable to accept this monoclimax view and consider that each markedly different type of site within a climate has its own climax of equal status with the rest, and consider this multiple climax conception to fit better the available information (15). The difference between the two views has perhaps been overstressed in some quarters and is perhaps not of very great practical importance (9).

The object of this address is to invite attention to the widespread occurrence of vegetational change both forward or successional and backward or retrogressional, and to the importance of the study of these phenomena with a view to their control for the benefit of the country. To what extent that objective has so far been attained may be indicated by the number and scope of ecological contributions to the Society's Journal in the future. Although Volume I has a useful paper by Dr. Dudgeon, there have been very few since.

References to Literature

1. BHARUCHA, F. R.—Problem of Grassland improvement in India, Curr. Sci. 1938, p. 600.

2. BLATTER, E. & HALLBERG, F.—Flora of the Indian desert. Jour. Bom. Nat. Hist. Soc. 1918.

3. BOR, N. L.—The vegetation of the Nilgiris, Ind. For. 1938, p. 600.

4. BOURNE, R.—Empire Forestry Journal, 1934, p. 15.

5. BURNS, W., KULKARNI, L. B. & GODBOLE, S. R.—Succession in xerophytic Indian grasslands, Journ. Eco. 1931, p. 389.

6. CHAMPION, H. G.—The influence of the hand of man on the distribution of forest types in the Kumaun hills. Ind. For. 1923, p. 116.

7. CHAMPION, H. G.—Regeneration and management of Sal (Shorea robusta). Ind. For. Rec. XIX (III) 1923.

8. CHAMPION, H. G.—A preliminary survey of the forest types of India and Burma. Ind. For. Rec., Silvi. I, 1, 1936.

9. CHAMPION, H. G.—Presidential address to Botanical Section Proc. Ind. Sci. Cong. 1937.

10. CLEMENTS, F. E.—Nature and Structure of the Climax, Jour. Eco. 1936, p. 252.

11. DUDGEON, W.—A contribution to the ecology of the Upper Gangetic plain, Jour. Ind. Bot. 1920.

12. HOLE, R. S.—Ind. For. Mem. 1 (1) 1911.

13. PHILLIPS, J.—Development of the Climax, Jour. Eco. 1935, p. 210.

14. RANGANATHAN.—Ind. For. 1938, p. 523.

15. VARMA, S. C.—Some ecological aspects of the Upper Gangetic Flora. Jour. Ind. Bot. Soc. 1936, p. 266.

DEVELOPMENT OF THE EMBRYO-SAC AND ENDOSPERM-HAUSTORIA IN SOME MEMBERS OF SCROPHULARINEAE

II

Isoplexis canariensis Lindl. and *Celsia coromandeliana* Vahl.

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In the first paper of this series the author (1937) described the formation of endosperm haustoria in *Sopubia Delphinifolia* and *Alonsia* species, and also made a brief reference to the work in hand on *Ilysanthes* and *Bonnaya*. During the early stages all these plants have four uninucleate micropylar haustoria and two uninucleate chalazal haustoria. In *Sopubia* there is a subsequent fusion of the micropylar haustoria to form one tetranucleate haustorium; and similarly a single binucleate haustorium is formed in the chalazal region by the dissolution of the separating membrane between the two cells. Thus the formation of the uninucleate haustorium is only an early phase in the development of a multinucleate haustorium with the consequent reduction in the number of haustorial cells. While the presence of two uninucleate haustoria or one binucleate haustorium at the chalaza is characteristic of the above named plants, there are genera like *Celsia* (Håkansson 1926) and *Digitalis* (Balicka Iwanowska 1899, Schmid 1906) where the presence of four uninucleate chalazal haustoria is the conspicuous feature.

Two species of *Celsia* have already been studied by Håkansson, and the present member is the third one to be investigated. As regards *Isoplexis* it may be pointed out that this is considered to be synonymous with *Digitalis*. Since there is variation in the haustorial formation, *Isoplexis canariensis* also was selected for investigation.

Materials and method.

Isoplexis was collected from the gardens at Ootacamund, and *Celsia* from the marshy areas round about Mysore. The material was fixed in chromc-acetic acid solution with a few drops of osmic acid added to it. For the structural details of the embryo-sac, the sections were cut 8 microns thick, while for the study of endosperm and haustoria the thickness of the sections was 12 microns. All the sections was stained in Heidenhain's iron-alum-haematoxylin.

The Ovule

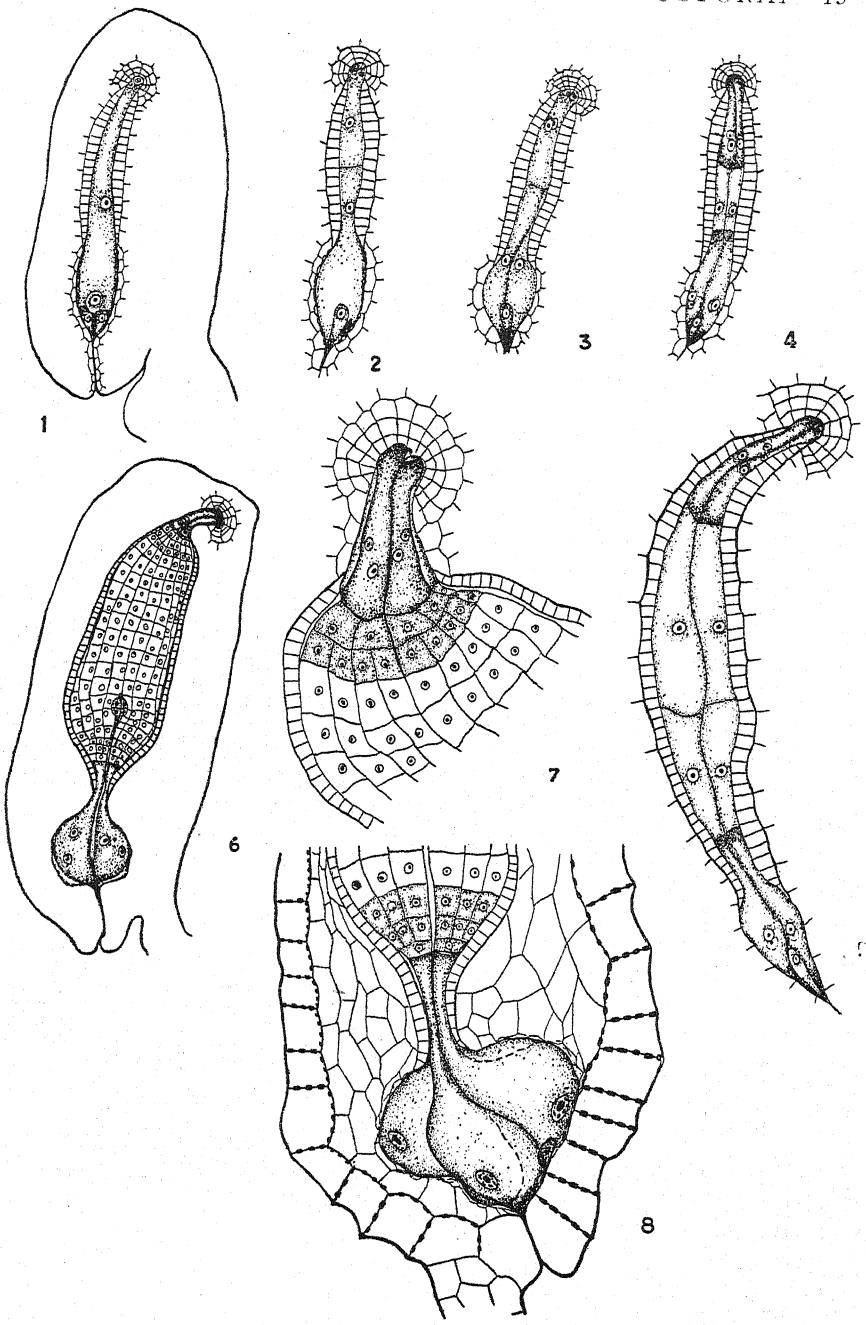
In both members the ovary has a thick placenta with the anatropous ovules arranged on it. As is usual in the sympetalae, there is a single massive integument, and the nucellus is much reduced. The integumentary tapetum surrounds the lower narrow portion of the embryo-sac. The cells of the placenta, integument and tapetum are all filled with oil globules and the ovules have a compactly arranged tissue of radiating cells with rich protoplasmic contents at the chalaza which becomes very conspicuous.

Isoplexis canariensis Lindl.

Embryo-sac :—The mature embryo-sac has a dilated micropylar end with the egg apparatus, and a narrow drawn out chalazal end with the three small antipodals. The two polar nuclei lie in the middle and fuse to form the secondary nucleus (Fig. I). The presence of the reduced synergids and antipodals which is so characteristic of all the members studied so far, is a common feature of this member also. The nucellar jacket is present especially near the dilated part of the embryo-sac, and its cells though reduced in size have rich protoplasm, and often store up starch grains in them.

Embryo and Endosperm:— Just as in forms described by me previously (1937), the stages in the development of the embryo are quite typical. The slower development of the embryo until the formation of a rich endosperm tissue, and its rapid growth soon after this are of interest.

Coming to endosperm formation, the sequence of divisions is similar to that in the plants previously investigated by me (1937). Of the three first formed cells, the middle one, by transverse and longitudinal divisions, develops into the endosperm proper, while the other two give rise to the micropylar and chalazal haustoria. It is worthy of note that some of the endosperm cells in the neighbourhood of the haustoria assume a food conducting role and form channels for conveying nutrition from the haustoria to the endosperm proper towards the interior. These cells are slightly smaller than the other endosperm cells but richer in protoplasmic contents and take a dark stain (Figs.7 and 8). The food in all endosperm cells is stored in the form of starch.



Text-Figs. 1-8. *Isoplexis canariensis* Lindl.

Fig. 1 Embryo-sac with the tapetum and the compact tissue at chalaza. × 130. Fig. 2 Initiation of the chalazal haustorial formation. × 160. Fig. 3 Longitudinal division of the above. × 130. Fig. 4 Formation of the micropylar and the endospermal tiers of cells. × 160. Fig. 5 Later stage showing the haustoria and endosperm developing. × 160. Fig. 6 Longitudinal section of a young seed showing the two kinds of haustoria, tapetum, endosperm and embryo. × 66. Fig. 7 Section showing the chalazal haustoria with the compact chalazal tissue and the conducting endosperm cells in the neighbourhood. × 320. Fig. 8, Later stage of micropylar haustoria, endosperm and seed-coat. × 160.

Endosperm haustoria:—The four micropylar haustoria are simple, unbranched and uninucleate but highly aggressive (Figs. 6 & 8). These are large and bulbous towards the micropyle and their inner ends are drawn out into long tubular structures which have funnel-like terminations in the proximity of endosperm (Fig. 8). Their nuclei enlarge conspicuously. The bulbous ends attack the integumentary cells and continue to digest them until, except for a little tissue near the micropyle, there is very little of the integument left between the persistent tapetum and the epidermal layer. Thus in the developing testa only the epidermal layer remains unaffected and its cells contain many oil globules. This layer in course of time becomes mechanical and protective in function (Fig. 8).

The cell cut off towards the chalaza similarly undergoes two longitudinal divisions to form four chalazal haustoria (Fig. 7). These are short club-shaped bodies, simple, unbranched and uninucleate, and are non-aggressive. They remain in contact with the compactly arranged radiating cells at the chalaza. Even during later stages their individuality is kept up indicating, that *Isoplexis* is less highly evolved than either *Hysanthes* or *Bonnaya*. The reduced size of the chalazal haustoria and the abutting tissue with its rich cell-contents make one doubt their haustorial efficiency in digestion and absorption. Whether it is the presence of this compact tissue which impedes the growth of the haustoria, or the aid rendered by this tissue in absorbing and conveying the nutrition to the haustoria making the further development of the latter unnecessary or superfluous, are questions that cannot be answered at present.

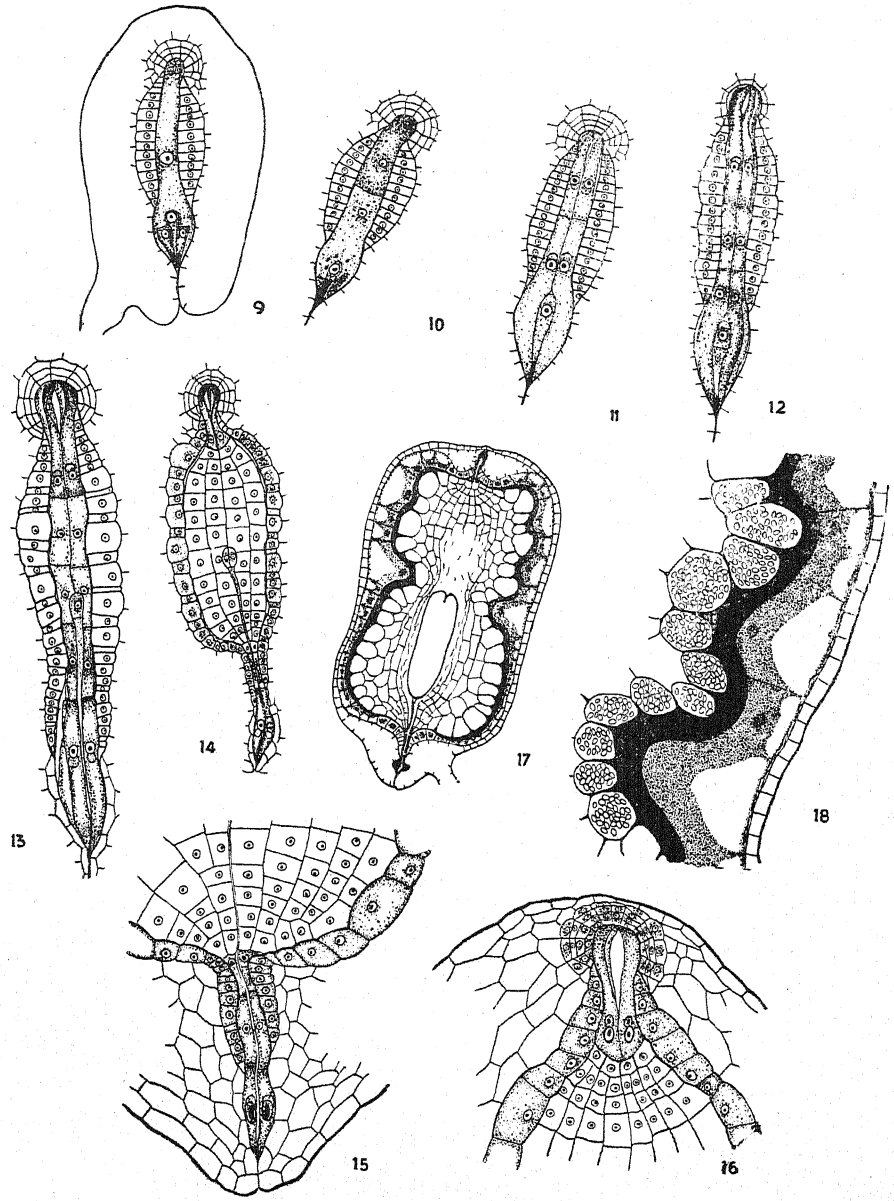
Later stages emphasize the early senility of the chalazal haustoria and the persistent nature of the micropylar ones. In both cases the nuclei become hypertrophied and amoeboid during older stages.

Celsia coromandeliana Vahl.

Embryo-sac :—There is no essential difference between this species and the last one either in shape or in structural details of the embryo-sac.

Fertilization:—The actual stages in syngamy or triple fusion were not observed, but the pollen tube was frequently seen in the micropyle as well as in the embryo-sac ; the latter process is accompanied by the destruction of one of the synergids as in *Isoplexis*.

Embryo and Endosperm:—The embryo is typically dicotyledonous as in the preceding form. Coming to the endosperm formation, it may be pointed out that the primary endosperm nucleus by transverse division followed by wall formation gives



Text-Figs. 9-18. *Celsia coromandeliana*, Vahl.

Fig. 9 Embryo-sac with tapetum and compact tissue at chalaza. × 235. Fig. 10 Separation of the chalazal cell. × 260. Fig. 11 Development of chalazal haustorium. × 235. Fig. 12 Formation of endospermal tier and the micropylar haustorial tier. × 235. Fig. 13 Later stage of the chalazal and micropylar haustoria. × 235. Fig. 14 Formation of embryo and endosperm and further development of the haustoria and active tapetum. × 95. Fig. 15 Older Micropylar haustoria with the conducting and storage portions of endosperm tissue. × 235. Fig. 16 Older chalazal haustoria with the endosperm and hypertrophied tapetal cells in the neighbourhood. × 235. Fig. 17 Longitudinal section of a seed showing the reduced seed-coat, hypertrophied tapetum and its lignified inner wall, the endosperm and the embryo. × 70. Fig. 18 A portion of the testa, tapetum and endosperm magnified. × 235.

rise to two chambers, the chalazal and the micropylar, the former developing directly into the chalazal haustoria, while the delimitation of the micropylar haustoria takes a somewhat longer time. The first two divisions of the micropylar chamber are longitudinal, and the four elongated cells thus formed divide transversely to form four haustorial and four endosperm cells (Figs. 11 & 12).

Endosperm Haustoria:—The chalazal chamber undergoes two longitudinal divisions to form the four chalazal haustoria. These are simple short, uninucleate and unbranched, and far from aggressive (Fig. 12).

The four micropylar haustoria are also short, simple, tubular and unbranched. It is peculiar that the senility and disorganization of the haustoria sets in at a time when there is the greatest demand for them by the developing endosperm and embryo. This makes one doubt their efficiency as digesting and absorbing organs for meeting the nutritional demands of the growing embryo and endosperm.

Tapetum and its role:—Just at the time when the haustoria are disorganizing, the tapetum becomes highly conspicuous. Some of its cells show a much greater increase in size than the others (see Figs. 13 & 14). This is probably due to lack of space for the full development of all the cells. At times alternate cells have been observed to enlarge, but in general there is no definite arrangement in the two kinds of cells. The structure of the tapetal cells, their increase in size at the time of disorganization of the haustoria, the large accumulation of the food material stored in them, and the gradual collapse of the integumentary tissue leaving only the epidermal layer in tact (Fig. 17) suggest that the tapetum has two distinct functions to perform, firstly the digestive one, since it digests and absorbs nutritive material from the integument, and secondly, its storage and subsequent transportation to the endosperm. It is also seen that the outer tangential and radial walls of its cells are devoid of thickenings while the inner tangential wall is very thick (Fig. 18). Such a thickening is noticeable even in some of the endospermal cells in the neighbourhood of tapetum. But towards the two ends of the embryo-sac, the tapetal cells are entirely thin walled, which is readily explained, if we regard these as the regions through which the nutritive material diffuses into the endosperm. Some of the endosperm cells also at these two ends are reduced in size and serve for food conduction as in *Isoplexis*.

A well-developed integumentary tapetum is of general occurrence not only in the members of the Scrophularineae but also in most other plants of the Sympetalae. Goldflus (1898 & 1899) and Schmid (1906) attribute a nutritive role to this layer, and many subsequent investigators like Schnarf (1917) and Lavialle (1912 & 1922) have endorsed the same opinion.

Since the epidermis of the developing testa is composed of small and thin-walled cells and does not assume a protective role, and since the entire tissue of the integument is already digested and utilised, this protective function has devolved on the tapetum. As already noticed, this layer is highly conspicuous by its size and the thick inner tangential wall, and the latter feature probably signifies this protective role. Thus it is observed that the tapetum, though primarily meant as a repository for food material, exhibits not only a probable haustorial action but also a mechanical or protective role on account of its peculiar position.

Summary

1. The presence of a reduced nucellus and a thick integument is common to these two members also.

2. The eight nucleate embryo-sac is met with in both the plants, and the integumentary tapetum surrounds the narrow region of the embryo-sac.

3. The chalaza is conspicuous by the presence of a tissue composed of radiating cells with rich contents, whose function has not yet been definitely understood.

4. In both the members, the early formation of four uninucleate chalazal haustoria, and the belated appearance of the micropylar haustoria also four in number and uninucleate, seem to be a characteristic and constant feature.

5. In *Celsia* all the haustoria are simple, reduced in size and non-aggressive, while in *Isoplexis* the micropylar haustoria are aggressive and happen to be large and bulbous towards the micropyle, and drawn out into funnel-like structures towards the endosperm. The nuclei in the haustoria become amoeboid and hypertrophied in the older stages.

6. Some of the tapetal cells in *Celsia* are highly conspicuous by their size, and these probably assist in the digestion and absorption of the tissue contents of the integument.

I wish to thank Dr. P. Maheshwari for his kind perusal of the manuscript and helpful criticism.

References

1. BALICKA-IWANOWSKA, G.—(1899)*. Contribution à 1' étude du sac embryonnaire chez certaines Gamopetales. Flora *86:* 47-71.

2. GOLDFLUS, M.—(1898/9)*. Sur la structure et le fonctions de l' assise épithéliale et des Antipodes Chez les Composées. Journ. Bot. France, *12*, 374-384; *13*, 9-17, 49-59, 87-96.

3. HÅKANSSON, A.—(1926)*. Zur Zytologie von *Celsia* und *Verbascum*. Lunds Univ. Arsskrift, N. F. Avd. *2*, *21*, Nr. 10.

4. KRISHNA IYENGAR, C. V.—(1937). Development of Embryo-sac and Endosperm-haustoria in some members of Scrophularineae 1. *Sopubia delphinifolia* G. Don. and *Alonsoa* sp. Journ. Ind. Bot. Soc. *16*, 99-109.

5. LAVIALLE, P.—(1922)*. Sur le rôle digestif de l' épiderme interne du tegument ovulaire des Composées. Bull. Soc. Bot. France, *69*, 75-79.

6. SCHMID, E.—(1906). Beiträge zur Entwicklungsgeschichte der Scrophulariaceae. Beih. Bot. Centralbl. *20* A, 175-299.

7. SCHNARF, K.—(1929). Embryologie der Angiospermen, Berlin.

* Quoted from Embryologie der Angiospermen by Schnarf, K. (1929).

GRAFTING OF FIGS

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Communicated by M. A. Sampathkumaran

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As in other fruits, the cultivation of figs affords many interesting problems such as the improvement of vigour, the yield of the plants and the quality of the fruits. In Mysore, in a village named Ganjam, the intensive cultivation of figs has been going on since 1800. The present work was undertaken with the idea of improving the vigour of these fig plants.

Figs are cultivated in Ganjam chiefly in the backyards of houses, surrounded by mud walls which serve as windbrakes. The red loamy soil seems to be very suitable for the vigorous growth of the plants. No manure is applied to these plants, but only frequent dressing of earth dug out of anthills and sand is given. The plants are propagated by layering the branches that are close to the ground. After a month when they strike roots, they are transplanted to the permanent pits. Cuttings are not usually employed for propagation on account of the very slow formation of the roots. It takes nearly three months for the plant to establish itself before it can be transplanted. The plants begin to bear fruits after a year and a half.

The problem of improving the vigour of the fig plant and its bearing quality by improving its root system has not so far been attempted. It was thought that, as in the case of the other fruit plants such as apples, etc., by providing a good rootstock, the vigour of the fig plant might be improved. Many rootstocks of the natural order Urticaceae were tried, and finally stocks of *Ficus religiosa* (peepul tree) and *Ficus glomerata* (wild fig tree) have been found to be most suitable. The scions were cleft grafted on the stocks at one inch above the ground level so as to prevent the rooting of the scion. The grafts were bound with raffia fibre. Buds on the scion developed after 16 days in the case of the grafts on both *Ficus religiosa* and *F. glomerata*.

In five weeks the development of the shoot was quite vigorous, and more pronounced than in the cuttings (Figs. 1 and 2).

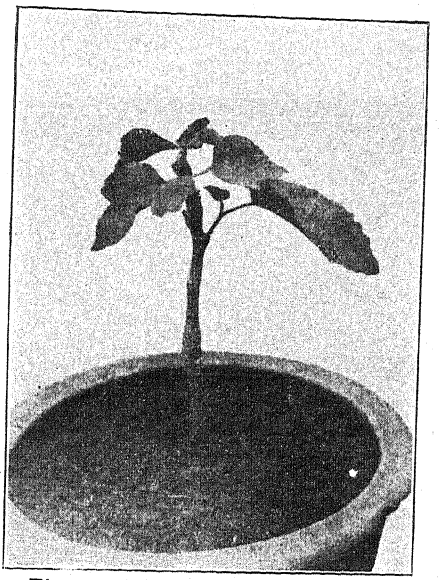

Fig. 1. Fig graft on *Ficus religiosa* five weeks old.

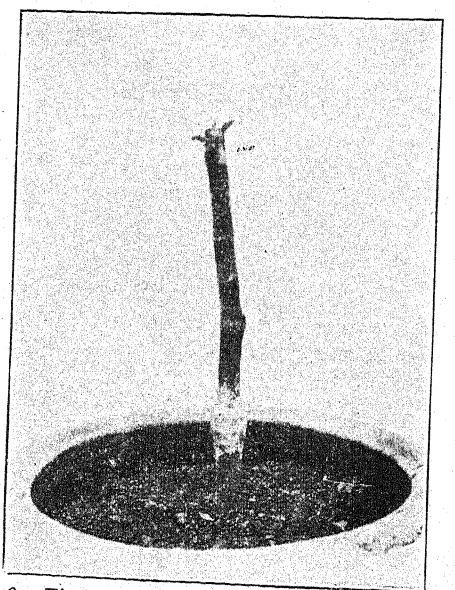

Fig. 2. Fig graft on *Ficus glomerata* 16 days old.

The two rootstocks chosen, viz. *Ficus religiosa* and *F. glomerata* have much to be said in their favour. They are large sized trees, with vigorous root systems, and capable of withstanding drought conditions. *F. religiosa*, especially, is so hardy that it grows even on temple walls.

The vigorous shoots put forth by these grafts, point out to a fair compatibility between the shoot and the scion; this question, however, will be studied later in more detail. The successful fig grafts thus established, indicate certain possibilities. It may be possible to grow these grafted figs even under dry conditions. The effect of the rootstock on the scion, with regard to vigour and bearing quality will be reported later.

My acknowledgements are due to Prof. Dr. M. A. Sampathkumaran, M.A., Ph.D., for the help given during the course of the work.

ON THE MECHANISM OF SPORE LIBERATION IN *PITHOPHORA POLYMORPHA* WITTR.*

BY

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Received for publication on 1st February 1939

Reproduction in *Pithophora* is effected by thick-walled resting spores characteristic of the genus. These spores are supposed to be set free from the mother plant by the death and decay of the adjoining cells. Wittrock (1877, p. 19) who established the genus states that the spores are "made free by the dissolution of the two cells situated one on each side of the spore". The author, while studying some living specimens of *Pithophora polymorpha* Wittr. at Madras, found that the spores were set free from the mother plant by a definite mechanism hitherto undescribed. Further material of the alga was collected from different localities in Madras and examined. These also showed the same method of spore liberation. Some living material of the alga got from Poona and kept growing in the laboratory also showed the same type of spore liberation.

The details of spore formation in this *Pithophora* are quite similar to those already recorded by Wittrock (1877). The spore formation takes place by the gradual migration of the cell-contents towards the upper end of the cell, which is then cut off from the lower portion by the formation of a cross wall. As a result, the original cell is divided into two portions, an upper shorter portion, rich in cell-contents, which forms the *spore*, and a lower longer cell called the *subsporal cell*. During the upward migration of the cell-contents to form the spore, all the protoplasm does not pass into the spore portion, but a small quantity is always left behind inside the subsporal cell. The quantity of protoplasm left behind is, however, so small, that, at first sight, the subsporal cell looks quite empty. Only a careful examination shows the presence of a thin layer of protoplasm more or less evenly distributed along the wall of the subsporal cell (Pl. I, Fig. 1). In this thin layer of protoplasm are present several

* From the Department of Botany, University of Madras.

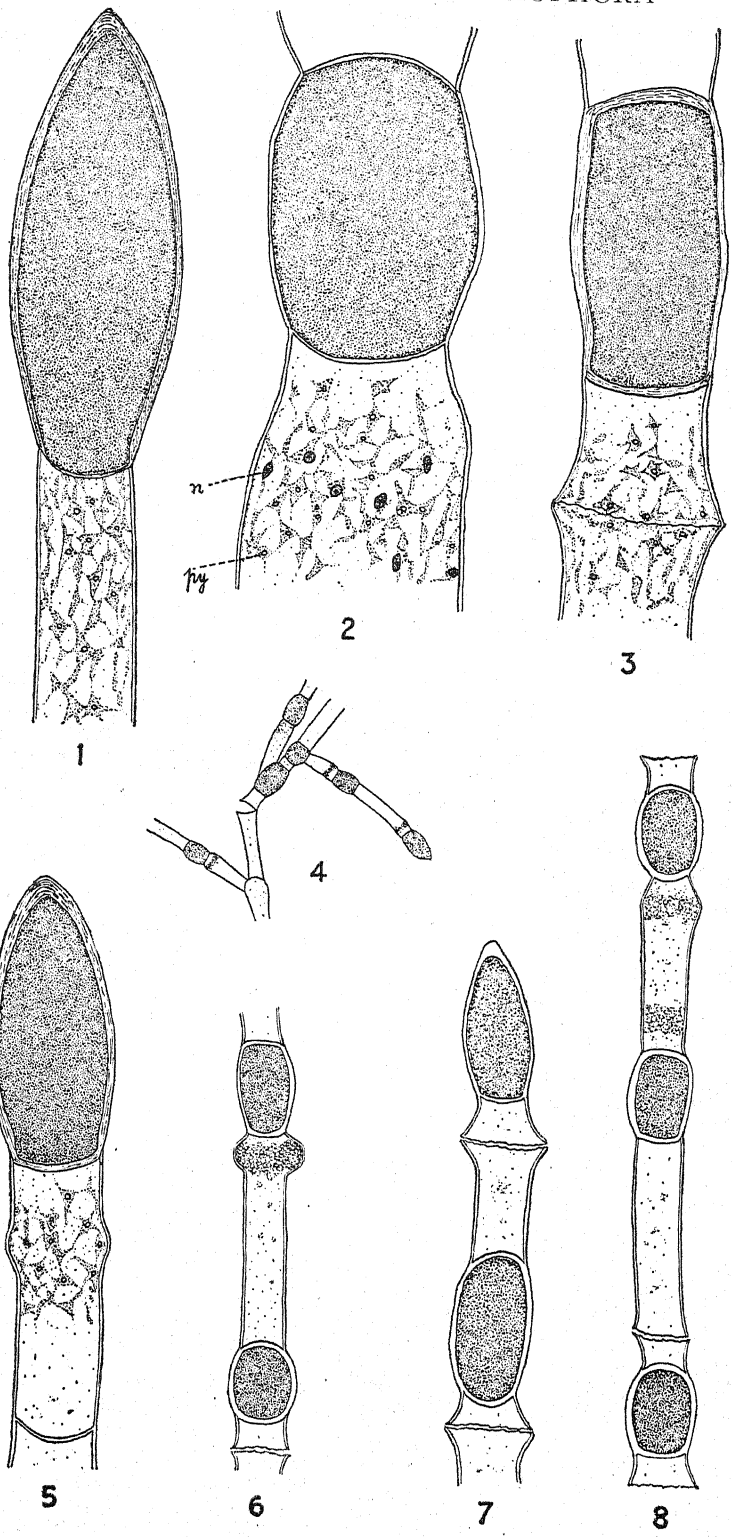
chloroplasts with pyrenoids imbedded in them and also quite a number of healthy nuclei (Text-fig. 2).

After the formation of the cross wall separating the spore portion from the subsporal cell, the thin layer of protoplasm in the latter, gradually moves upwards and begins to accumulate near the upper portion (Text-fig. 1). Here the protoplasm becomes more and more compact and finally forms a ring-like band a little below the spore portion (Text-figs. 2-5). By this time, the lower portion of the subsporal cell becomes practically empty of all protoplasm. Soon after the formation of this ring-like band of cell-contents, the wall of the cell at that region shows signs of swelling (Text-figs. 3, 5, 6; Pl. I, Figs. 2, 3, 5). After the formation of the swelling, there is seen a fine circumcissal split in the cell-wall all round the swelling (Text-fig. 3). This break soon becomes more prominent and finally quite complete and brings about the separation of the spore from the subsporal cell (Text-figs. 4, 6, 7, 8; Pl. I, Figs. 2, 5, 6).

Regarding the way in which the break of the subsporal cell is brought about, it seems very probable that the ring-like accumulation of protoplasm secretes a sort of an enzyme which helps in the dissolution of the wall at this region. As the cell-wall, due to this dissolution, becomes weakened, the turgor pressure exerted by the cell sap evidently causes the wall to get distended at this region, and brings about the formation of the characteristic annular swelling. As the dissolution of the wall progresses further, the swelling also increases still more and finally the cell-wall gets completely ruptured in a circumcissal manner.

Thus it is clearly seen that the spores in *Pithophora* are liberated from the adjoining portions by a circumcissal break brought about by the activity of the living protoplasm left behind in the subsporal cells. In other words, the spore is liberated by a definite organic process and not through the mere decay of the dead neighbouring portions. It looks as though the alga, while forming its spores, also makes a definite provision for their eventual liberation from the plant body.

Text-figs. 1-8. *Pithophora polymorpha* Wittr.—Fig. 1. A terminal spore with a portion of the subsporal cell, showing the accumulation of the cell-contents below the spore. × 210. Fig. 2. An intercalary spore with the portion of the subsporal cell showing the presence of chloroplasts, pyrenoids and nuclei inside (from a permanent preparation stained in iron alum haematoxylin). *n*. nucleus; *py*. pyrenoid. × 210. Fig. 3. Beginning of the break in the subsporal cell at the swollen region. × 210. Fig. 4. A portion of a plant showing the breaking of a subsporal cell. × 33. Fig. 5. A terminal spore with the ring-like swelling just developing, in the subsporal cell. × 210. Fig. 6. Two intercalary spores, the lower one already cut off from the subsporal cell below, while a ring-like swelling is formed below the upper spore; note the dense accumulation of the cell-contents inside the swelling. × 65. Fig. 7. Terminal portion of a filament showing two spores already cut off from their respective subsporal cells. × 105. Fig. 8. Two bands of cell-contents formed in the upper subsporal cell; the spore at the lower end already free from the filament; note the break formed at the lower end only in the lower subsporal cell. × 65.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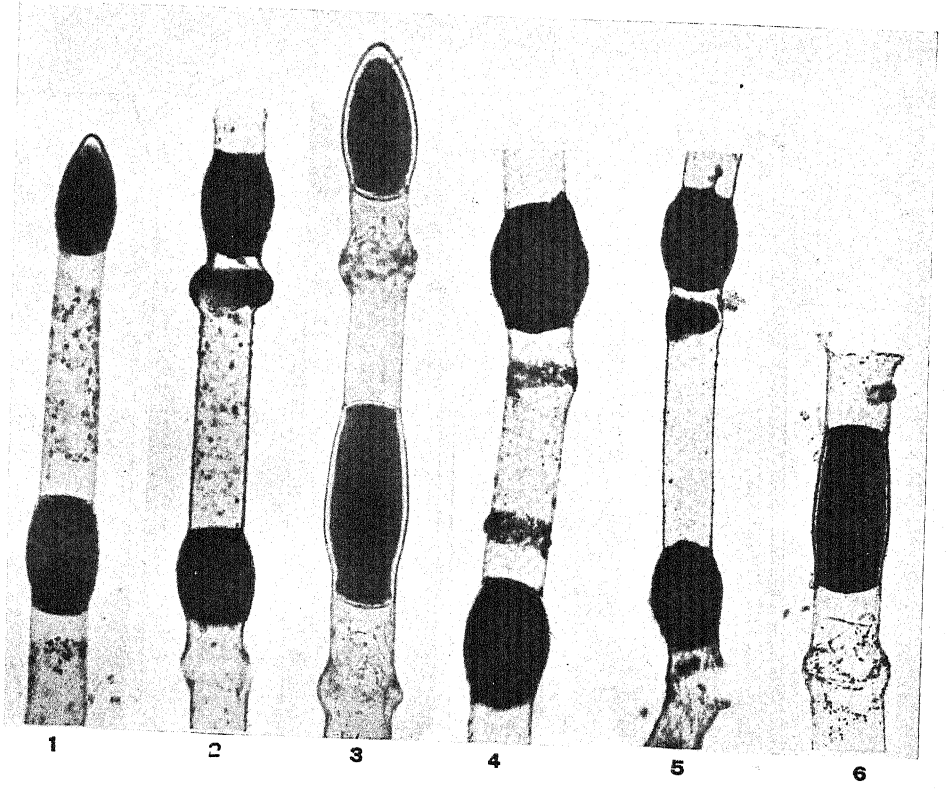
Usually the ring-like accumulation of the protoplast takes place only at the upper end of the subsporal cell. But quite frequently a similar ring-like formation takes place at its lower end also (Text-fig. 8; Pl. I, Fig. 4). This is brought about by the migration of the thin layer of protoplasm in the subsporal cell, partly upwards and partly downwards. When two such rings are formed, a circumcissal break takes place both at the top and at the bottom. Very occasionally the break of the filament takes place at the lower end only (Text-fig. 8).

Very often no ring-like formation of the cell-contents is seen in the subsporal cells. An examination of such subsporal cells generally shows that the cells are not quite healthy, but are damaged in some manner, often through the attack of a fungal or protozoan parasite. In such cases, the spores continue to remain attached to the dead subsporal cells and are liberated only by the decay and disintegration of these portions.

A reference to the literature shows that this method of spore liberation has not been observed by any of the previous authors. Wittrock (1877) considered the subsporal cells "as being at least half dead" and thought that the spores were liberated by the dissolution of the adjoining cells. Ernst (1908) also states that the membrane of the dead cells becomes disorganised and the spores are set free. But Mothes (1930), however, observed that the subsporal cells are capable of forming more cell-contents if they are placed under favourable conditions and that they are even able to form a second spore. Möbius (1895) alone amongst the several previous workers observed the ring-like swelling below the spore. He stated that this swelling was probably brought about by the thinning of the membrane at the region and that the consequent swelling was due to turgor pressure inside the cell. He stated, however, that it had no further significance. But, in the explanation of his figure, (Möbius, 1895, fig. 8), he states that the filament breaks off easily at these ring-shaped swellings. He did not, however, recognise the fact that the formation of this ring-like swelling is a stage in a vital process on the part of the plant in bringing about the liberation of the spore. Brand (1905) figures a ring-shaped swelling below the spore in *P. macrospora*, but does not refer to it either in his description of the alga or in his explanation of the figure.

SUMMARY

An account is given of the mechanism of spore liberation in *Pithophora polymorpha* Wittr. The release of the spore does not take place by the mere decay of the thallus as is usually believed, but is brought about through the activity of a small quantity of living protoplasm left inside the subsporal cell, when the spore is formed. Through the activity of this living protoplasm in the



K. R. RAMANATHAN — *PITHOPHORA POLYMORPHA* WITTR.

subsporal cell, a ring-like swelling is formed below the spore and soon a circumcissal break of the filament takes place at this region and liberates the spore from the filament.

In conclusion, I wish to express my great indebtedness to Prof. M. O. P. Iyengar, M.A., Ph.D. (Lond.), F.L.S., Director, University Botanical Laboratory, Madras, for his valuable help and guidance in the preparation of this paper.

Literature Cited

BRAND, F. (1905).—Uber die Anheftung der *Cladophoraceen* und über verschiedene polynesische Formen dieser Familie. Beih. Bot. Centralbl., Bd. XVIII, Abt. I, pp. 165-193.

ERNST, A. (1908).—Beitrage zur Morphologie und Physiologie von *Pithophora*. Ann. d. Jardin Bot. Buitenzorg. Vol. XXII, 2nd Ser., Vol. VII, pp. 18-55.

MÖBIUS, M. (1895).—Beitrag zur Kenntnis der Algengattung *Pithophora*. Ber. d. deut. Bot. Gesellsch. Bd. XIII, pp. 356-361.

MOTHES, K. (1930).—Morphologische und physiologische studien an der *Cladophoracee Pithophora*. Ber. d. deut. Bot. Gesellsch. Bd. 48., pp. (110)-(121).

WITTROCK, V.B. (1877).—On the Development and Systematic arrangement of the *Pithophoraceae*. Nova Acta Reg. Soc. Sc. Upsala, Ser. 3.

Explanation of Plate I

Figs. 1—6. Photomicrographs showing stages in the liberation of the spore in *P. polymorpha* Wittr.

Fig. 1.—Thin cell-contents inside the subsporal cell evenly distributed along the wall. (× 61·5)

Fig. 2.—Ring-like accumulation of the contents of the subsporal cell and the swelling below the spore; filament already ruptured below the lower spore. (× 61·5)

Fig. 3.—Terminal portion of a filament showing the formation of a ring-like swelling below each spore ; note the accumulation of the cell-contents at the regions. (× 61·5)

Fig. 4.—Formation of two bands of cell-contents, one at each end of the subsporal cell. (× 61·5)

Fig. 5.—Break of the filament below the lower spore. (× 61·5)

Fig. 6.—A spore already cut off from the upper subsporal cell and in the process of being separated from the lower one. (× 61·5)

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ANATOMICAL STUDY OF *HOLMSKIOLDIA SANGUINEA* RETZ. (VERBENACEAE)

BY

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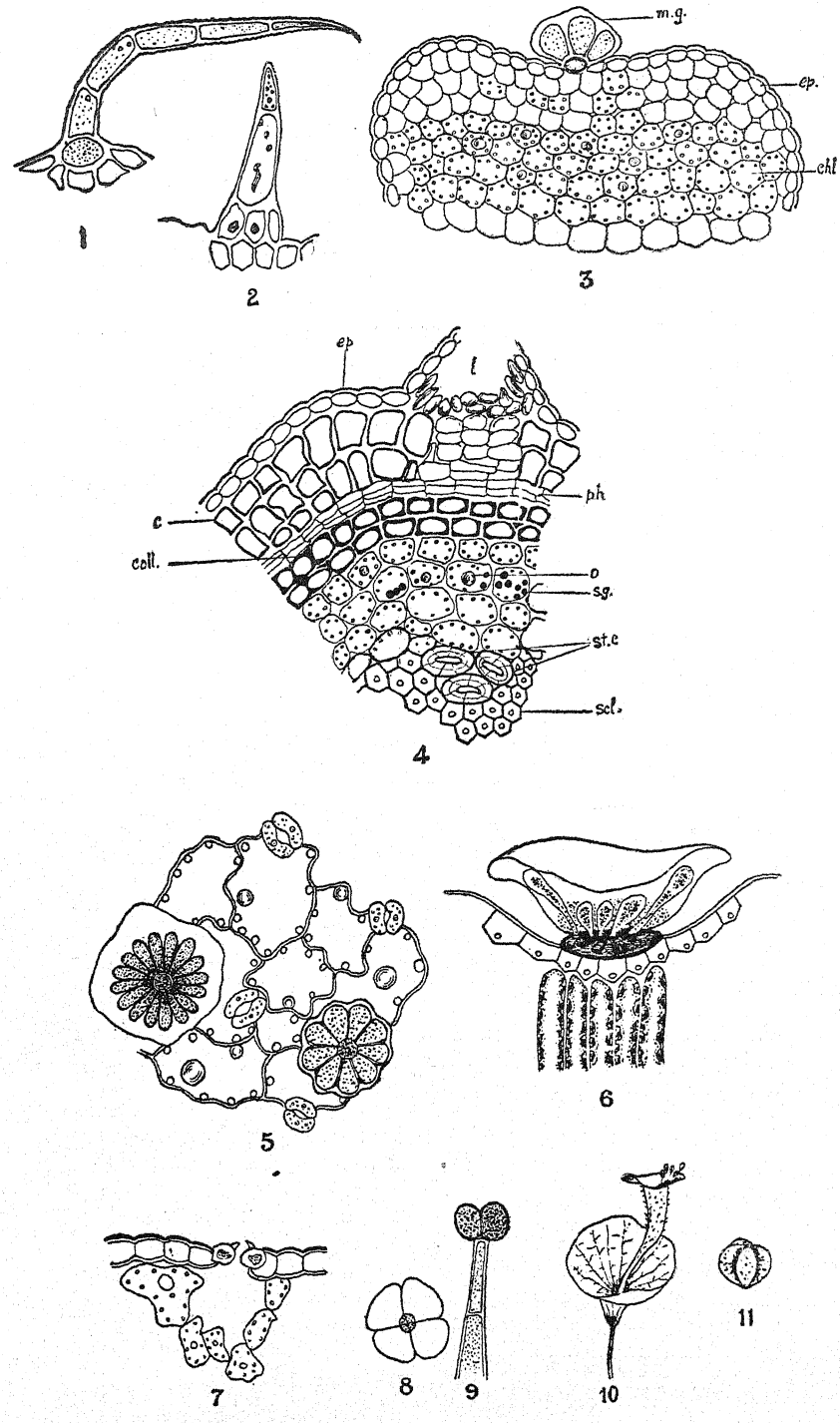
Received for publication on 21st February, 1939

Holmskioldia sanguinea Retz. H.F.B.I., IV, 596, is a native of sub-tropical Himalaya. It is a straggling shrub with brick-red flowers in cymes, and is very conspicuous because of its subrotately campanulate petaloid calyx which reaches a diameter of 1 inch in fruit. In the available literature no reference is found regarding the anatomy of this plant. Hence this investigation was taken up.

Oxalate of lime occurs in all parts of the plant in the form of prismatic, rod-like, simple or aggregate crystals, although these are very meagre in the root.

The hairy covering consists of uniseriate trichomes of two kinds, (*a*) long hairs provided with small knobs and mostly bent at an angle to the stalk (Fig. 1) and (*b*) short straight conical hairs (Fig. 2). Both these are abundant on the upper surface of the leaves. Besides these ordinary clothing of hairs, depressed peltate, bladder-like glands similar to those of the Labiatae (Solereder) occur in the epidermis of the lamina, petiole and young stems (Figs. 3, 5 & 6), though they are less abundant in the latter.



Text Figs. 1—11. *Holmskioldia sanguinea*, Retz.

Fig. 1. Uniseriate bent trichome (× 350). Fig. 2. Uniseriate straight conical trichome (× 350). Fig. 3. T.S. Young stem—m.g. a peltate gland; ep, epidermis; chl, chlorenchyma in primary cortex (× 200). Fig. 4. T.S. old stem—ep, epidermis; l, lenticel; c, cork; ph, phellogen;

Young stems are very hairy, and contain mucilage-glands (Fig. 3, m.g.). They are quadrangular in section. Stomata are present in the epidermis of the herbaceous portions of the stem. There is no hypodermis as is described by Mullan in the case of *Clerodendron*. Starch grains and oil globules occur in the chlorenchyma of the primary cortex. Collenchymatous cells are also present in this region. Phellogen is situated just above the primary cortex. Cork consists of one or two layers of tabular lignified cells. Lenticels have been observed (Fig. 4, l). In the pericycle, isolated patches of sclerenchymatous fibres occur. Mixed amongst these, stone cells are found (Fig. 4, st. c). An endodermis is present. Starch containing cells are met with in the pericycle as well as in the medullary rays and pith, where they are most abundant.

The leaf is bifacial, and contains oil in the region of the mesophyll. Stomata occur only on the lower epidermis (Figs. 5 & 7). Besides the ordinary trichomes referred to above, peltate glands (Figs. 5 & 6) occur in depressions on both the surfaces, but are more abundant on the lower. The glands consist of a big basal cell from which palisade-like cells, about 12-16 in number, radiate. They are covered by a bladder-like expansion of the cuticle.

The structure of the root is quite normal. Starch grains are met with in the cortical parenchyma. They are fewer in the medullary rays.

Peltate glands are present in the upper epidermis of the calyx, and in the outer epidermis of the corolla. In addition to these, glandular hairs (Figs. 8 & 9) are also met with. They are more abundant on the corolla than on the calyx. The glandular hairs consist of a long uniseriate stalk and a spherical head, which is divided vertically into four parts.

Peltate glands with very dense contents are most abundant on the wall of the ovary (Fig. 11). Their secretion makes it very sticky, and gives the test for mucilage.

Literature Cited

HABERLANDT, G.—Physiological Plant Anatomy. Engl. Ed. 1928.

HOOKER, J. D.—Flora of British India. IV, 1885, p. 596.

MULLAN, D. P.—Observations on the Biology and Physiological Anatomy of Some Indian Halophytes. Jour. Ind. Bot. Soc. XII, 2, pp. 165—179.

SOLEREDER, H.—Systematic Anatomy of the Dicotyledons. Engl. Ed., Oxford, 1908, pp. 630—635.

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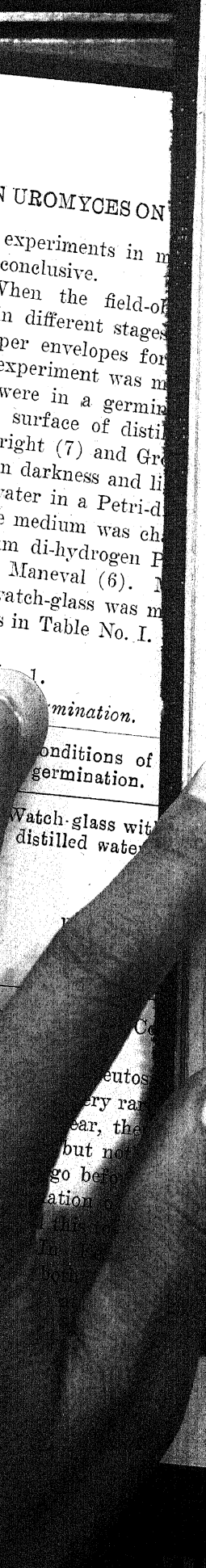
coll., collenchymatous cells; o, oil globules; s.g., starch grains; st. c., stone cells; scl. sclerenchymatous fibres (× 350). Fig. 5. Leaf lower epidermis, showing stomata, oil globules and peltate glands in surface view (× 350). Fig. 6. T.S. leaf, showing a peltate bladder-like gland, and palisade cells (× 400). Fig. 7. T.S. leaf, showing a stoma and spongy tissue (× 350). Fig. 8. Glandular hair in surface view (× 200). Fig. 9. The same in side view. Fig. 10. Flower, showing glandular hairs on the corolla (about 2/3 natural size). Fig. 11. Gland-dotted ovary (× 6).



DEVELOPMENT OF EMBRYO-SAC AND ENDOSPERM-HAUSTORIA IN SOME MEMBERS OF SCROPHULARINEAE

III

Limnophila heterophylla Benth, and *Stemodia viscosa*, Roxb.

BY

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The first two papers of this series (Krishna Iyengar 1937, 1939) describe the formation of the endosperm haustoria in *Sopubia delphinifolia*, *Alonsoa* sp, *Isoplexis canariensis* and *Celsia coromandeliana*. In the last two members the presence of a chalazal nutritive tissue composed of compactly arranged radiating cells with rich contents is noteworthy, and the author has pointed out its possible effect on the development of the chalazal haustoria. A similar situation is met with even in *Gratiola* (Glisic 1933) where the presence of a nutritive chalazal tissue and the nonfunctional nature of the haustoria have been emphasised. In *Celsia* both micropylar and chalazal haustoria are reduced in size, but their disorganization is accompanied by a conspicuous enlargement of some of the tapetal cells which thus come to play an important role in the nutritional physiology of the endosperm and embryo.

In *Isoplexis* and *Celsia* the number of micropylar and chalazal haustoria is four each, and all are uninucleate. A series may be arranged beginning with forms like these and ending with others like *Paulownia tomentosa* (Millsaps 1936) where a single binucleate haustorium of each kind is present from the beginning. Such a series would be characterised by a tendency towards a reduction in the number of the haustoria often accompanied by an increase in the number of nuclei in each haustorium. This is clearly seen in *Sopubia*, *Alonsoa* and many others where the fusion of uninucleate haustoria towards the formation of a bi- or a tetranucleate body is a common feature. While *Paulownia* has a binucleate haustorium, *Gratiola* goes a step further in as

much as it has a single uninucleate chalazal haustorium. Several members of the Gesneraceae (Glisic 1924) and a few of the Bignoniaceae (Mauritzon 1935) have similar chalazal haustoria; the latter family is specially noted for the uninucleate micropylar haustoria in some of the members.

This paper describes the author's observations on *Limnophila heterophylla* and *Stemodia viscosa* which show a general similarity of habit and habitat.

Materials and Methods

The two plants were collected from the shallow ponds and pools near Agumbe in the western ghats during the first week of October 1937. The material was fixed in chromo-acetic acid solution with osmic acid. For the study of the embryo-sac the sections were cut at 8 microns, and for the endosperm and haustoria at 12 microns. The preparations were stained in Heidenhain's iron alum haematoxylin.

The Ovule

Both the species have a large ovary with a thick placenta and numerous anatropous ovules. There is a single thick integument and the nucellus is very much reduced. Innumerable starch grains are found deposited in the cells of the integument. The integumentary tapetum surrounds the lower portion of the embryo-sac in *Limnophila*, while in *Stemodia* it is the upper portion that is surrounded. The lower half of the ovule is richer in cell contents than the upper.

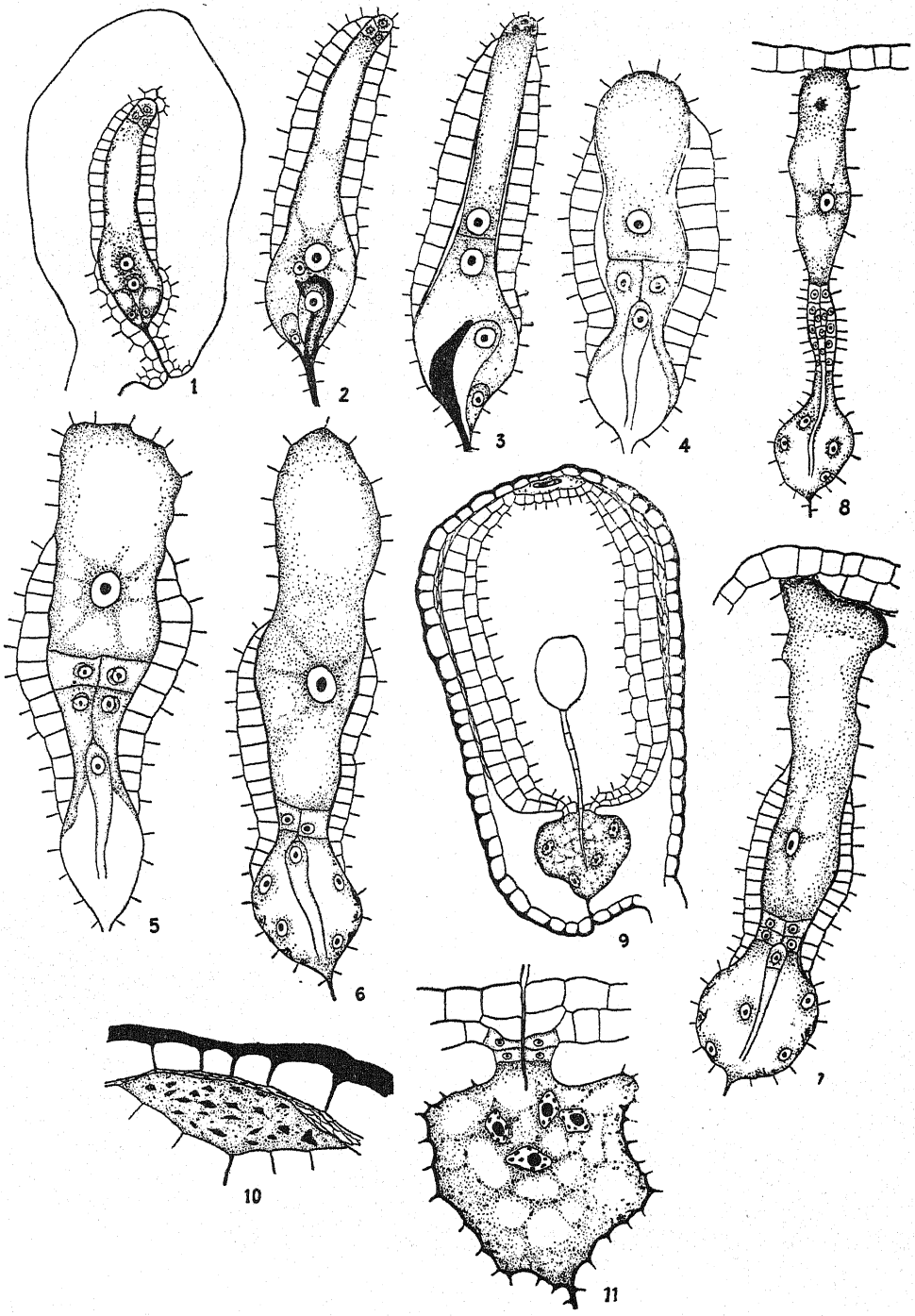
Limnophila heterophylla, Benth.

Embryo-sac:—The embryo-sac is of the normal type. The egg apparatus lies in the slightly dilated micropylar end of the sac. Just before fertilization the two polar nuclei fuse in the middle to form a secondary nucleus which shows a tendency to be in close proximity to the egg. The chalazal part of the embryo-sac which is comparatively broader than in the previously studied forms contains the three small antipodals. The protoplasm of the sac is highly vacuolated, such vacuolation being specially conspicuous in the neighbourhood of the egg apparatus and secondary nucleus (Fig. 1).

Fertilization:—Pollen tubes were frequently seen in the micropyle and the embryo-sac. An actual fusion of the nuclei was not noticed, but the presence of a sperm nucleus near the secondary nucleus and the destruction of one of the synergids (Fig. 2) strongly suggest that fertilization takes place normally. The antipodals degenerate soon after fertilization.

Embryo and Endosperm:—The fertilized egg slowly elongates into a tubular body and divides only after the formation of

Fig. 6. Formation of a tetra-nucleate micropylar haustorium and a uninucleate chalazal haustorium. × 320. Fig. 7. Further development of the haustoria and endosperm. × 235. Fig. 8. Slightly older stage than fig. 7. × 160. Fig. 9. Diagram of longitudinal section of an older ovule showing the well-developed endosperm, micropylar haustorium and embryo, and degenerating chalazal haustorium. × 130. Fig. 10. Chalazal haustorium, old stage showing the disorganised nucleus. × 730. Fig. 11. Micropylar haustorium old stage showing four amœboid nuclei. × 320.



Figs. 1-11. *Limnophila heterophylla*, Benth.

Fig. 1. Longitudinal section of ovule showing embryo-sac surrounded by the tapetum. × 320. Fig. 2. A stage in the fertilization. × 480. Fig. 3. First division of primary endosperm nucleus completed. × 480. Fig. 4. Longitudinal division of the micropylar chamber. × 480. Fig. 5. Formation of the micropylar and the endospermal tiers of cells. × 480.

a large number of endosperm cells. The developmental stages of the embryo do not essentially differ from the other members of the family already described by me.

The division of the primary endosperm nucleus is followed by the formation of a transverse wall, separating a large chalazal chamber from a smaller micropylar one (Fig. 3). The latter undergoes two longitudinal divisions resulting in four cells (Fig. 4), which now divide transversely separating a micropylar tier of four cells from the middle tier composed of the same number (Fig. 5). The middle tier forms the body of the endosperm, while the chalazal chamber and the micropylar tier develop into the haustoria. As compared to the part given over to the formation of the haustoria, the endospermal tier is very much reduced in size (Figs. 7 and 8). In the mature endosperm two regions are noticeable, a storage tissue in the middle composed of large cells filled with starch grains and a compact tissue towards the two ends composed of smaller cells devoid of starch but richer in protoplasm and taking a darker stain. The latter connects the storage tissue with the haustoria, thus having probably a food conducting rôle (Fig. 11).

Endosperm haustoria :—The large chalazal chamber whose origin has been mentioned already is responsible for the chalazal haustorium which is the first to differentiate (Figs. 3 and 4). Its nucleus does not divide but enlarges conspicuously. It seems probable that with its increased volume this single nucleus is able to regulate the haustorial activities of this chamber and that a division of either the nucleus or the chamber is unnecessary. Thus the chalazal haustorium develops into a large uninucleate body whose lobed lower end is highly aggressive, and so thoroughly digests its way through the integumentary tissue at the chalazal end that it comes to lie directly against the epidermal cells of the developing testa (Figs. 7–9). All that is seen of the intervening cells is just some bits of the cell wall, sticking out here and there into the haustorium. It is also noticeable that the commencement of degeneration of this organ synchronises with the greatest development of the micropylar haustoria. The depletion of the cell-contents in the lower half of the ovule and the accumulation of darkly stained materials in the upper half of the same, noticed at this stage, form a significant feature. This may mark the approaching senility of the chalazal haustorium and the commencement of the micropylar haustorial activity.

As mentioned before, the micropylar chamber cuts off four uninucleate haustoria. These are simple and unbranched (Figs. 4 and 5) but fuse at an early stage to form a large aggressive, bulbous, tetranucleate body. This persists for a long time and aids in the digestion and absorption of the tissues of the integument. The cytoplasm of the haustorium is richly vacuolated and contains many large granular bodies. A few bits of the walls of disorganised cells are noticed even in this haustorium.

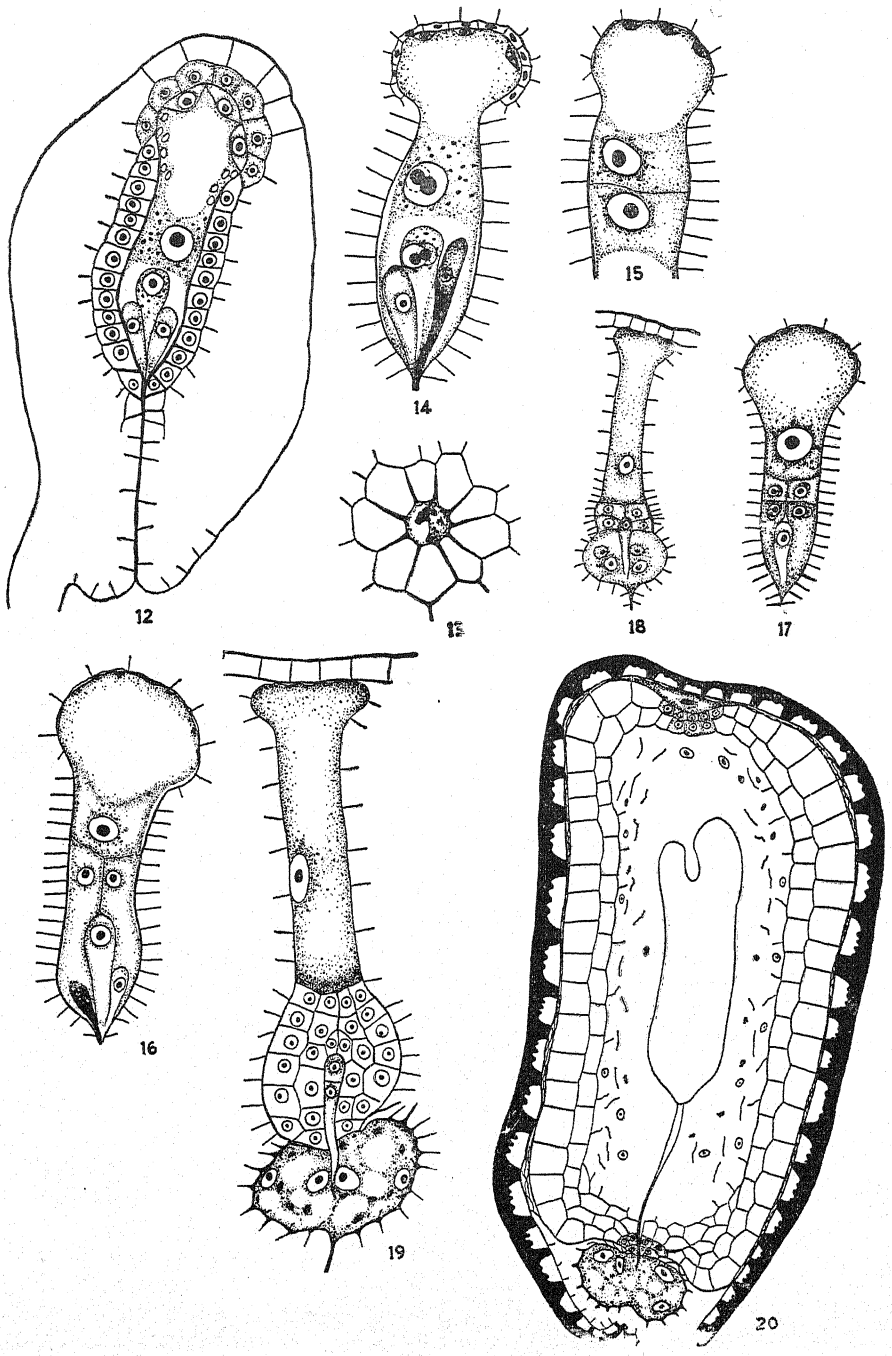
In older ovules the chalazal haustorium is greatly reduced in size and shows a densely stained rod-shaped nucleus (Fig. 9) which is very conspicuous. The small notch seen on the seed coat at this region is probably due to the collapse of the haustorium and the destruction of the neighbouring tissue. The nucleus often disintegrates into small irregular bits scattered in the cytoplasm as shown in Fig. 10. On the other hand the micropylar haustorium is a highly enlarged persistent body, and its nuclei are hypertrophied and amoeboid and rich in chromatin material (Fig. 11). The digestion of the integumentary tissue in this region is so thorough that only a few cells are left in the neighbourhood of the micropyle (Fig. 9).

Stemodia viscosa, Roxb.

Embryo-sac :—Considering the size of the ovule the embryo-sac of this plant is shorter and stouter than that of *Limnophila*. Also, it is so deeply placed that there is only a single layer of cells separating the chalazal end of the sac from the outer epidermis of the ovule. This separating layer is rich in cell contents (Fig. 12). Unlike the previously investigated members, the chalazal end of the sac enlarges here in a conspicuous manner and becomes vacuolated (Fig. 12). As has already been mentioned the integumentary tapetum surrounds the middle portion and the tapering micropylar part of the sac leaving the dilated chalazal end free, this feature being a peculiarity in this plant. The tapetal cells surrounding the micropyle in the neighbourhood of the embryo-sac are specially conspicuous by the thickening of their radial walls as seen in Fig. 13. The significance of this thickening is not yet clear. The large antipodals are loosely placed in the dilated chalazal end of the sac, and are conspicuous by their large nuclei. While the enlargement of the antipodals may be due to greater space available to them, it is also quite probable that this end of the sac is concerned with the absorption of nutritive material from the integument much before the chalazal haustorium is actually laid down. The presence of a large quantity of starch in this region lends further support to this view. The protoplasm in the neighbourhood of the egg apparatus is richly granular. The secondary nucleus lies in the middle of the sac.

Fertilization :—The presence of the pollen tube in the micropyle and in the embryo-sac, and the destruction of one of the synergids were frequently noticed. Fig. 14 shows a stage in double fertilization. Even at this stage the activity of the chalazal end of the sac is noticeable in as much as the cells in the neighbourhood have begun to collapse (Fig. 14).

Endosperm and embryo :—The endosperm and embryo develop as in *Limnophila*. The early initiation of the chalazal and micropylar chamber and the separation of a middle tier of cells from the micropylar one take place in the same way (Figs. 16 & 17).



Figs. 12-20. *Stemodia Viscosa*, Roxb.

Fig. 12. Longitudinal section of the ovule showing the tapetum and embryo-sac with large antipodal cells. × 480. Fig. 13. Transverse section of tapetum at the micropylar end of the embryo-sac showing the thickening of the radial walls. × 480. Fig. 14. Fertilization of the egg and secondary nucleus. × 730. Fig. 15. Division of the primary endosperm nucleus followed by a transverse wall formation. × 640. Fig. 16. Enlargement of the chalazal chamber and the first longitudinal division of the micropylar

Just as in *Limnophila* the chalazal haustorium is uninucleate and aggressive and begins to function very early. The micropylar haustoria, laid down at a later stage, are at first uninucleate but soon afterwards form a single tetra-nucleate body which begins its maximum activity after the chalazal haustorium has degenerated. The haustoria thus show a useful periodicity in their formation as well as activity which is common to both the species.

Summary

(1) The embryo-sac is of the normal type, and the polar nuclei fuse to form the secondary nucleus just before fertilization.

(2) In *Stemodia* the integumentary tapetum sheathes the non-dilated micropylar and middle portions of the embryo-sac, while in *Limnophila* the dilated micropylar portion of the sac is devoid of it.

(3) In *Stemodia* the chalazal part of the embryo-sac becomes greatly dilated even before fertilization, and the accumulation of starch in this region suggests that it plays a role in the nutrition of the sac before the laying down of the haustoria.

(4) In both the forms the early initiation of a large and aggressive uninucleate chalazal haustorium seems to be a noteworthy feature.

(5) Four uninucleate micropylar haustoria are laid down at first, but they soon fuse to give rise to a single tetra-nucleate body. In later stages the nuclei become amoeboid and hypertrophied.

(6) The endospermal cells adjacent to the haustoria are of a smaller size and probably assist in the transmission of food materials absorbed by the haustoria to the more centrally situated cells of the endosperm.

(7) The chalazal haustorium begins to degenerate as soon as the micropylar haustorium is well developed.

Grateful acknowledgment is made to Dr. P. Maheshwari who was kind enough to peruse my paper and offer helpful suggestions.

References

(1) GLISIC, Lj.,—1924.* Development of the X-generation and embryo in *Ramondia*. Diss. Belgrad, pp. 95.

(2) ————1933. Zur Entwicklungsgeschichte von *Gratiola officinalis* L. Bull. Inst. Jard. Bot. Univ. Beograd. *2*, 129-152.

* Cited in Embryologie der Angiospermen by Schnarf, K. (1929).

chamber. × 480. Fig. 17. Second longitudinal division and the separation of a middle tier from the micropylar tier. × 320. Fig. 18. The formation of a tetra-nucleate micropylar haustorium and progressive growth of the uninucleate chalazal haustorium. × 160. Fig. 19. Older stage of the haustoria, endosperm and embryo. × 320. Fig 20. Longitudinal section of nearly mature seed showing the older haustoria, embryo, endosperm and other parts. × 160.

(3) KRISHNA IYENGAR, C.V. 1937.—Developement of the Embryo-sac and Endosperm-haustoria in some members of Scrophularineae. I. *Sopubia delphinifolia* and *Alonsoa* sp. Jour. Ind. Bot. Soc. *16*, 99-109.

(4) ————1939. Development of the Embryo-sac and Endosperm-haustoria in some members of Scrophularineae. II. *Isoplexis canariensis* and *Celsia coromandeliana*. Jour. Ind. Bot. Soc. *18*, 13-20.

(5) MAURITZON, J. 1935.—Etwas über die Embryologie der Bignoniaceen. Bot. Notiser, Lund, 60-77.

(6) MILLSAPS, V. 1936.—The structure and development of the seed of *Paulownia tomentosa*. Jour. Elisha Mitchell Sci. Soc. *52*, 56-75.

THE PRIMARY VASCULAR SYSTEM OF THE STEM OF *NYCTANTHES ARBORTRISTIS* L.

BY

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Communicated by A. C. Joshi

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The stem of *Nyctanthes arbortristis* L., Fam. Oleaceae, differs from that of normal dicotyledons in possessing cortical bundles. A transverse section of an internode (Fig. 1) shows four cortical bundles in the four angles of the squarish stem situated to the outside of the normal ring. The structure of the normal ring is of the usual kind. It is not differentiated into separate bundles. The only other notable feature is that outside the ring of xylem and phloem there is a band of sclerenchymatous fibres, a feature which Solereder* regards as characteristic of the Oleaceae. The cortical bundles are peculiar in that they are inversely orientated. The xylem is found towards the outside and phloem towards the inside.

As the structure of the vegetative stem of *Nyctanthes* is of an unusual kind, it was thought worth while to follow the course of the primary vascular bundles through a node and study the origin of the cortical bundles and their relation to other bundles of the stem and the leaf traces. For this purpose series of sections were cut through a number of nodes and the changes in the vascular system were followed.

Figs. 2—9 illustrate one such series of sections through a node from above downwards. The pair of leaves arising from this node, as is shown by the figures, was found to be unequally developed. This is a quite common condition in this species in the young stages. The axillary buds in this series were found to be poorly developed (Figs. 3 and 4) and their vascular system had not much differentiated. The leaf traces consist of three bundles. There is one large central bundle and on either side of it there is a small bundle (Figs. 2 and 3). On approaching the node, the smaller bundles

* Solereder, H. Systematic Anatomy of the Dicotyledons. English translation. Vols. I & II. Oxford, 1908.

begin to divide and form generally two, but sometimes even three or four bundles (Figs. 3 and 4). They may also at this stage show some connections with the central bundle of the leaf traces (Figs. 4—6). The leaves now fuse with the stem and the vascular ring of the latter opens up on the sides of the leaves to form the common foliar and ramal gaps. The cortical bundles of the upper internode remain undivided or fork into two. The

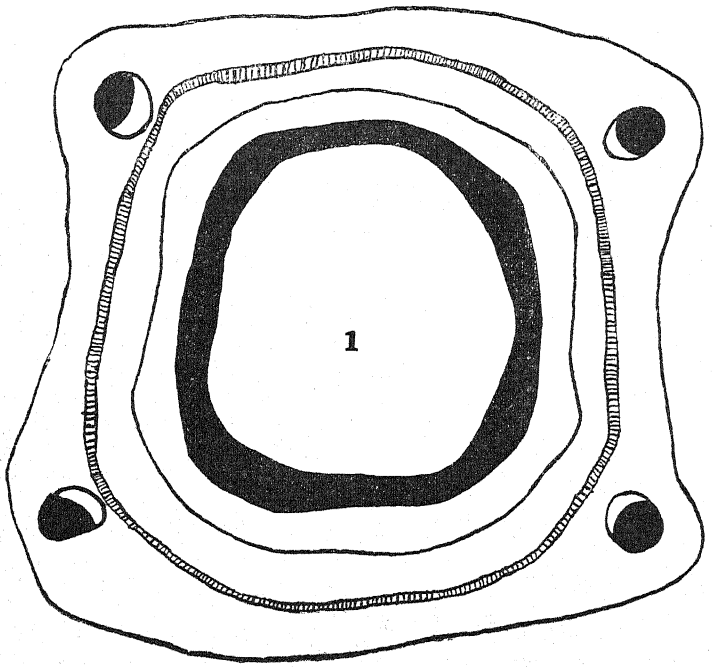
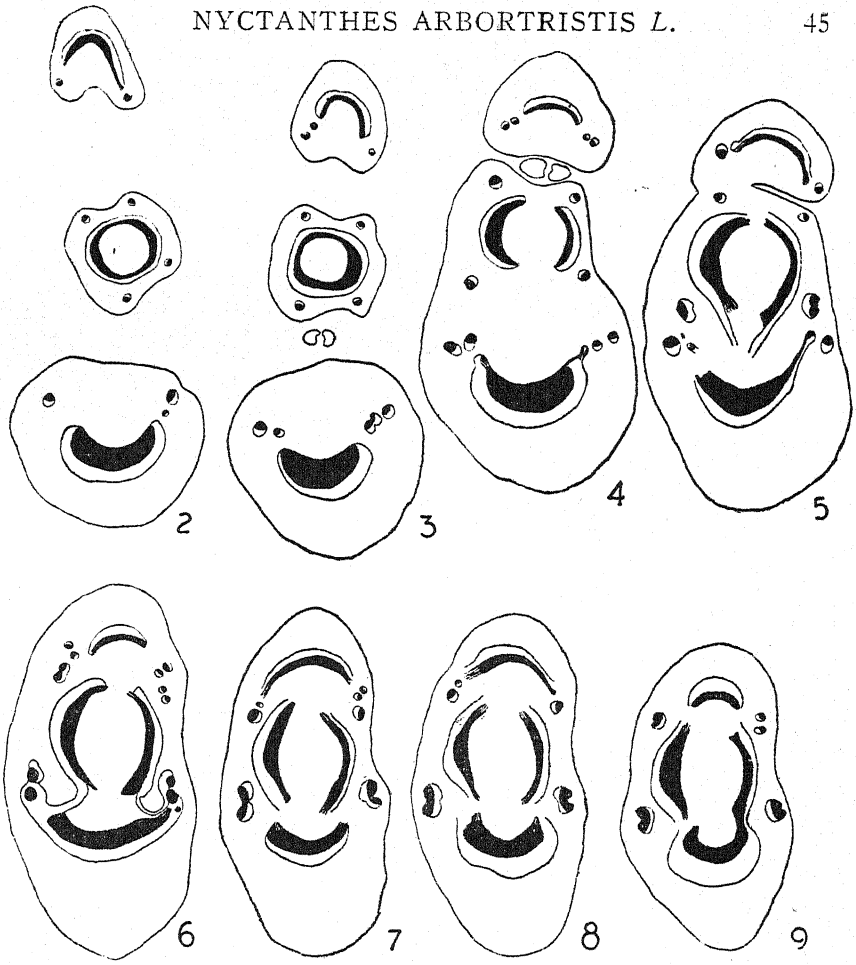


Fig. 1. *Nyctanthes arbortristis.* Transverse section of the stem through an internode. Xylem is shown by black, phloem white and fibrous pericycle by hatching. For further explanation see text. × 50.

lateral bundles of the leaf traces or their branches now undergo a twist so that their xylem begins to face outwards like that of the cortical bundles of the stem. Still lower down the lateral leaf trace bundles and the cortical bundles of the upper internode fuse to form the cortical bundles of the lower internode (Figs. 7—9). The central leaf trace bundles move inwards and complete the normal ring of the lower internode (Figs. 6—9). The nodes above and below this node were found to show the same changes. It thus appears that the entire primary vascular system of *Nyctanthes arbortristis* is of the common type. The normal ring of the stem is formed from the central leaf trace



Figs. 2—9. *Nyctanthes arbortristis.* A series of transverse sections through a node with unequally developed leaves from above downwards to show the course of vascular bundles. Xylem is shown black and phloem white. For further explanation see text. × 50.

bundles and the cortical bundles from the lateral leaf trace bundles.

Summary

The stem of *Nyctanthes arbortristis* L. shows besides the normal ring four inversely orientated vascular bundles in the four angles of the stem. The leaf traces consist of a large central and two small lateral bundles. The normal ring of the stem is formed from the central leaf trace bundles, while the cortical bundles arise from the small lateral leaf trace bundles.

The writer is indebted to Dr. A. C. Joshi for suggesting this investigation and help in the preparation of this note.

HIGHER FUNGI OF THE PUNJAB PLAINS

1. The Gasteromyceteae

BY

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The sandy wastes and the river beds of the Punjab Plains abound in several forms of the higher fungi (Basidiomycetes) and they appear in large numbers during the monsoon rains, especially in August and September. The forms described here were collected during the years 1933 to 1938, chiefly in the Districts of Sheikhupura, Gurdaspur and Sargodha, and most of them belong to the family Tylostomaceae of the group Gasteromyceteae. The specimens have been identified with the aid of such literature as was available at Lahore and New Delhi and most of the identifications have been confirmed or determined by Dr. W. C. Coker of the University of North Carolina. The specimens have been deposited in the writer's own herbarium and in the Herb. Crypt. Ind. Orient. of the Imperial Agricultural Research Institute, New Delhi. Many of them are also in the Herbarium of the University of North Carolina.

Family Tylostomaceae

This family contains plants of very divergent affinities, but is treated here as defined by Cunningham (1925). According to him, the family contains the genera *Podaxon, Phellorinia, Chlamydopus, Tylostoma, Quéletia* and *Battarrea*, but Lloyd (1906) had included all these in one family with the exception of *Podaxon* and *Phellorinia*, and in a later note he stated "*Phellorinia* belongs to the family *Tylostomaceae* and was omitted from our pamphlet through oversight". The genus *Phellorinia* was doubtfully referred to the family *Sclerodermataceae* by Fischer (1933), but in a recent paper (1936) he has shifted it to the family *Podaxineae*, which includes all the genera included by Cunningham in the family Tylostomaceae.

As defined by Cunningham (1925) the family contains "those genera in which the gleba consisting of spores and a definite capillitium, is carried within a two layered peridium

supported at the apex of a definite elongated stem (which traverses the gleba in *Podaxon*)".

Of the six genera included in this family, those found in the Punjab Plains are *Podaxon, Phellorinia, Battarrea* and *Tylostoma*. The genus *Podaxon* with its percurrent columella, *Battarrea* with peculiar elater like cells in the gleba and *Phellorinia* with large fugacious scales on the peridium can be easily distinguished from one another. The genus *Tylostoma* contains small plants with the stalk inserted in a socket at the base of the peridium.

Each of the three genera *Podaxon, Phellorinia* and *Battarrea* is represented by a single species in the Punjab. The genus *Tylostoma* is represented by large number of species; and in addition to those described here there are some still lying with the writer, awaiting determination.

PODAXON Fries

1. **Podaxon distillaris** (L.) Fries, Syst. Mycol. 3: 63, 1892. Syn. *P. aegyptiacus* Mont., *P. arabicus* Pat., *Podaxis indica* (Spreng.) Massee.

Plants upto 16 cm. in height. Peridium ovate oblong upto 7·6 cm. long and 3·2 cm. diameter. Exoperidium in the form of large white appressed fugacious scales. Endoperidium membranous white to pale brown, becoming smooth in the ripe specimens; wrinkled in old dried herbarium specimens; apex bluntly acuminate or rounded: opening by becoming free from the stem at the base, accompanied by longitudinal splits going towards the apex upto various extents. Stem upto 8·2 cm. tall and upto 0·85 cm. diameter, traversing the gleba as a percurrent columella, attached with the apex of the peridium; covered with white irregularly arranged scales; produced below into a thick rhizomorph.

Gleba passing through various shades of colour with age, varying from olivaceous through reddish brown to almost black; capillitium olivaceous or reddish brown; threads sparingly branched with few septa. Spores obovate or ellipsoidal, reddish brown 10-16 x 9-12μ apically truncate; smooth; with an apical germ pore.

Sargodha; Sangla Hills; Rohtak. Solitary in sandy soils. (Plate I, Fig. 1.)

The plant varies a good deal as to colour of the gleba, the capillitium and the spore characters and recently Morse (1933) has gone to the extent of including all the species under *Podaxon carcinomalis*, and accordingly Dr. Coker also referred the writer's plants to it.

PHELLORINIA Berkeley

2. **Phellorinia inquinans** Berk. Hook. Journ. Bot. 2: 417,1843
Syn. *Xylopodium Delasteri* Mont.; *X. australe* Berk.; *Xylopodium Aitchisonii* Cooke and Mass.; *Phellorinia australis* (Berk.) Lloyd; *P. californica* Peck; *P. Delasteri* (Mont.) Fischer; ? *Whetstonia Strobiliformis* Lloyd.

Plants upto 9 cm. in height; Peridium 4 to 4·7 cm. long, 4·6 to 5 cm. in diameter. Exoperidium whitish covered with large thin irregularly arranged scales without any longitudinal or concentric markings, which fall off as the plants reach maturity. Endoperidium membranous, smooth, white, continuous with the stem rupturing by irregularly breaking away at the apex, and becoming urceolate. Stem 4·3 to 5 cm. tall, 1·3 to 1·5 cm. diameter covered with fibrillose scales, slightly bulbous at the base; base produced into a thick rhizomorph formed by hyphae and sand particles in the ground. In one plant peridium was sessile. Gleba pulverulent, brown; capillitium scanty, made up of shreds; spores globose; subhyaline to hyaline; epispore medium; rough, slightly, verrucose; 5 to 7μ in diameter, mean being 6μ.

Sargodha; Rohtak.—Solitary in sandy soil. (Plate I, Fig. 2.)

A widely distributed but rare plant, characterized by the caducous scales, scanty capillitium and the mode of dehiscence. Cunningham (1925) reduces *P. australis* (Berk.) Lloyd to synonymy of this species. Cited by Butler and Bisby (1931) as *Xylopodium Aitchisonii* Cooke and Mass.

BATTARREA Persoon

3. **Battarrea Stevenii** (Libosch.) Fries Syst. Myc. 3: 7, 1829
Syn. *Dendromyces Stevenii* Libosch.; *Sphericeps lignipes* Welw. and Currey.; *Battarrea Gaudichaudii* Mont.; *B. Guicciardiniana* Ces.; *B. Muelleri Kalchb.; B. Tepperiana* Ludw.; *B. laciniata* Underwood.

Peridium depressed, globose, seated at the apex of the stem, 5·1 cm. in diameter and 2·8 cm. in height; upper part having a portion of the outer coat of the volva adhering to it. Stipe 11·1 cm. long, 1·5 cm. thick covered with long coarse fibrillose overlapping scales, which are numerous, tending to peel off near the apex; surrounded at the base by two layered volva, (the specimen at hand shows a third inner layer thus recalling the triple volva of *B. digueti* described by White (1901). Outer volva 7·6 cm. in diam. and 7·2 cm. high, slightly tapering at the base where it is 3 cm. in diameter of dull white colour; inner layer is 2·5 cm. in diameter, and about 4·2 cm. high of the colour of the stipe.

Gleba pulverulent, with capillitium consisting of long hyaline threads and spirally or annularly thickened elaters (characteristic

of the genus). The latter range from 40·9 × 7·5μ to 74·4 x 5·6μ in size. Spores globose or subglobose; finely punctulate; yellowish brown, with rather thick epispore; granular contents; 5·9 to 7·2μ in diameter, mean being 6·5μ.

Rohtak. Solitary on the ground with volva hidden by the soil. (Plate I, Fig. 3.)

In Engler and Prantle's book (1933) Fischer adopts the name *B. Guicciardiniana* Ces. while *B. Stevenii* is reduced to a synonym; but this is against the well-established rules of nomenclature.

TYLOSTOMA Pers.

4. **Tylostoma squamosum** Pers. Sys. Meth. Fung. P. 135, 1801 Syn. *Tylostoma Barlae* Quelet ; *T. mammosum* (Mich.) Fr. var. *squamosum* (Gmèl.) Fries.

Peridium globose or depressed globose; upto 1·1 cm. in diameter 0·7 cm. in height. Exoperidium dark coloured; rough (not granular) occasionally separating imperfectly. Endoperidium reddish brown opening by a definite tubular very slightly projecting mouth.

Stipe upto 3·5 cm. long and 0·25 cm. thick; strongly scaly, scales caducous; of reddish brown colour; stuffed.

Gleba ferruginous; capillitium of hyaline branched threads with many septa; strongly swollen at the nodes; spores ellipsoidal or globose; ochraceous; with granular contents; epispore medium thick; with rather prominent blunt echinulate spines; 4·1 to 5·6μ in diameter; mean 4·9μ.

Gurdaspur. Solitary in sandy soil. (Plate II, Fig. 5.)

Characterized by its rough reddish brown peridium and a strongly scaly stem.

5. **Tylostoma verrucosum** Morg. Journ. Cin. Nat. Hist. 12: 164.

Peridium depressed globose, upto 1·8 cm. in diameter, 0·6 cm. in height. Exoperidium thin, adnate, verrucose, becoming smooth with age. Endoperidium of light brown colour, opening by a definite slightly projecting tubular mouth.

Stipe upto 1·3 cm. long; 0·2 cm. thick; strongly scaly of brown colour; with a thick mycelial base.

Gleba pale ferruginous; capillitium of hyaline threads; sparsely septate; little or not swollen at the nodes. Spores globose ellipsoidal; yellowish; epispore thin; sparsely echinulate; 3·7 to 4·5μ in diameter but averaging 4·05μ.

Gurdaspur. Solitary on the ground. (Plate II, Fig. 2.)

Lloyd (1906) published a beautiful photograph of this species and the writer's plants perfectly agree with it. It resembles very closely *Tylostoma squamosum* in having large caducous scales, but the plants of the two species can easily be distinguished from each other by the exoperidium and the colour of the plants. *Tylostoma verrucosum* is a smaller plant with a large mycelial base.

Lloyd states that the exoperidium is persistent, but the writer has seen the verrucose exoperidium adhering in patches only in a few specimens, the rest having a smooth endoperidium.

6. **Tylostoma pygmaeum** Lloyd Myc. Writ. 2: 16, 1906.

Peridium globose upto 0·9 cm. in diameter, 0·7 cm. in height. Exoperidium adhering, separating imperfectly, particles adhering to the peridium, thickened and persistent at the base. Endoperidium white; membranaceous; opening by a definite tubular strongly projecting mouth.

Stipe upto 2 cm. long; 0·2 cm. thick, striate, not scaly stuffed.

Gleba ferruginous; capillitium of hyaline; sparsely septate threads; strongly swollen at the nodes. Spores globose, ellipsoidal; sub-hyaline or hyaline; epispore thin; echinulate, but echinulations not very distinct; 3·3 to 4·1μ in diameter, averaging 3·8μ.

Gurdaspur. Solitary in sandy soil. Fairly common (Plate II, Fig. 6).

Characterized by having the exoperidium adhering in the form of small particles, white colour of the endoperidium and a strongly projecting tubular mouth. The spores in the writer's specimen are slightly smaller in size than in the type.

Coker and Couch (1928) consider that it differs from *T. floridanum* Lloyd in the unimportant character of colour.

7. **Tylostoma mammosum** (Mich.) Fries, Syst. Myc. 3:42, 1829.

Syn. T. *brumale* Pers.

T. *pedunculatum* (L.) Schroter.

Peridium globose or sub-globose upto 0·7 cm. in diameter, 0·5 cm. in height. Exoperidium completely falling away and remaining attached near the base in adhering patches. Endoperidium membranous smooth, cream coloured, opening by a well developed concolourous tubular mouth.

Stipe upto 1·9 cm. long, 0·25 cm. thick, very rarely breaking into small scales, of lighter colour than the peridium.

Gleba ferruginous; capillitium of hyaline slender threads; very many septa; very strongly swollen and rounded at the

nodes. Spores spherical to globose; yellowish to sub-hyaline; epispore medium thick; verrucose, tuberculate (mammose); 4·5 to 5·6μ in diameter; mean 5·3μ.

Sargodha. Solitary on the ground. (Plate II, Fig. 4.)

It is the nearest approach to the European plant, from which it differs in its colour, but resembles in all other features. It is specially characterized by its non-scaly stem, tubular concolourous mouth; tuberculate spores and swellings of the capillitium nodes.

8. **Tylostoma Mac-Alpinianum** Lloyd Myc. Writ. 2: 15, 1906.

Peridium depressed globose upto 1·5 cm. in diameter, 0·8 cm. in height. Exoperidium separating imperfectly adhering in irregular patches on the endoperidium. Endoperidium dirty white with a small tubular circular slightly protruding mouth. In one specimen as many as three mouths were seen.

Stipe upto 3·6 cm. long and 0·5 cm. thick, striate, pale yellowish, stuffed.

Gleba pale ferruginous; capillitium hyaline, branched, septate; septa slightly swollen. Spores globose to ellipsoidal; sub-hyaline to ochraceous; epispore thin, smooth, 4·1 to 5·2μ diameter, mean 4·7μ.

Gurdaspur, Sangla Hill. Solitary or in groups in grass. (Plate II, Fig. 7.)

Sometimes plants are seen growing united with one another by their stalks. Characterized by pale ferruginous gleba, a definite slightly protruding mouth and dirty white colour of the peridium and occasionally with patches of the exoperidium adherent to it.

Cunningham (1925) has amended the original description of Lloyd, but the Indian plants closely resemble the original description of the species. As Cunningham lays too much stress on spore characters, his form may be a new species or at least a new variety. The species closely resembles *Tylostoma albicans* White, from which it is very difficult to separate. The writer sent some plants to Dr. Coker for confirmation, who stated that it may be either *Tylostoma albicans* or *Tylostoma Mac-Alpinianum*. Except for the spores and scales on the stem there are no other characters to distinguish between the two and even these characters are very variable and White (1901) states in the original description of *T. albicans*, that the spores may be smooth or if rough only a few of them so.

9. **Tylostoma occidentale** Lloyd Myc. Writ. 2: 13, 1906.

Peridium depressed globose, 0·74 cm. in diameter, 0·4 cm. in height. Exoperidium adhering, separating imperfectly to expose a white thin endoperidium. Endoperidium white thin opening

by a well defined, not at all or slightly projecting mouth. (A very small ring like are around the mouth where the exoperidium has just separated is very characteristic.)

Stipe 0·15 cm. thick, 0·8 cm. long, striate or very rarely breaking into small scales; dirty white; stuffed.

Gleba ferruginous; capillitium of branched, sub-hyaline or hyaline threads which are either narrow, or strongly swollen at the nodes. Spores globose, ellipsoidal, very dilutely yellow, epispore thin, smooth, 3·7 to 5·2μ in diameter, mean 5·25μ.

Sangla Hill. Solitary in sandy soil. (Plate II, Fig. 3)

A very small species with white endoperidium; definite mouth, and smooth spores. The capillitial threads differ from the type in having swollen nodes, but in the same preparation several threads are seen which have little or not at all swollen nodes.

10. **Tylostoma australianum** Lloyd Myc. Writ. 2: 20, 1906.

Peridium globose, sub-globose or pulvinate upto 1·4 cm. in diameter, 1·15 cm. in height. Exoperidium a sandy coat completely falling away leaving a nearly smooth endoperidium. Endoperidium membranous of dirty white colour, opening by a slightly raised irregular aperture.

Stipe 2·4 cm. long; 0·4 cm. thick striate, stuffed.

Gleba ferruginous; capillitium of hyaline slender threads; septa few, swollen. Spores globose to ellipsoidal; ochraceous; epispore thick, smooth; 5·4 to 6·3μ in diameter, mean 5·7μ.

Sangla Hill. Solitary in sandy soil. Fairly common. (Plate II, Fig. 8)

Whereas the Punjab specimens closely correspond to the original description of Lloyd, Cunningham (1925) describes plants for which he has to amend the original description. From his description it is evident that he is describing a different plant, when he remarks that the species is characterized by an indifinite plane mouth, scaly stipe and verrucose spores. The Punjab specimens resemble his, only in possessing an indefinite plane mouth, but strongly differ in having smooth spores and striate, not scaly stipes. It is the commonest species in the Punjab plains, and no specimen has ever been found showing any variations from the type.

11. **Tylostoma egranulosum** Lloyd Myc. Writ 2: 21, 1906

Peridium oblong, globose or sub-globose, upto 1·8 cm. in diameter, and 1·5 cm. in height. Exoperidium in the nature of a sandy case which separates with a pitted effect on the endoperidium, but persisting as a distinct collar at the base of the peridium. Endoperidium dingy white, opening by an irregular

slightly raised mouth, which is torn and granular in some aged specimens.

Stipe upto 2·5 cm. long, and 0·5 cm. thick, striate, of a lighter colour than the peridium, becoming dark in very old specimens, stuffed, sometimes very few scales.

Gleba ferruginous; capillitium of long branched threads; sub-hyaline, of the diameter of spores or narrower, sparsely septate, swollen at the nodes, transverse or oblique septa. Spores globose to spherical, apiculate, yellowish or ochraceous, epispore medium thick, smooth, 4·5 to 6·5μ in diameter, mean 6·5μ.

Sangla Hills. Solitary in sandy soil. Fairly common. (Plate II, Fig. 10).

A collection from Gurdaspur resembles the above as to the mouth and pitted peridium, but varies as to size and colour, which is white. The spores are spherical and ellipsoidal, slightly yellowish punctulate, epispore medium thick, verrucose, 3·7 to 5·6μ in diameter; mean 4·8μ.

The plants of this species were sent to Dr. Coker for confirmation, who referred it to *T. Punctatum* Peck. and wrote further "In our book we gave this as a form of *Tylostoma campestre* Morg., but it may be distinct." He is evidently impressed by the pitted nature of the endoperidium which is a constant feature of all the plants in the collection. But in a still later note he remarks that "*Tylostoma punctatum* is probably not different from *Tylostoma egranulosum* of Australia (see Lloyd). As Lloyd notes *Tylostoma campestre* is the American representative of *Tylostoma egranulosum* Lev. of Europe, and *T. punctatum* has been considered a form of *campestre*. On the other hand Lloyd described *Tylostoma egranulosum* as very close to *T. granulosum*, so that all the four species are practically the same thing." But according to Cunningham (1932) *T. Readeri* is a synonym of *T. egranulosum* so the five species should be regarded as the forms of one species, with only slight local variations.

There are occasionally seen several abnormal plants which closely resemble *Tylostoma egranulosum*, except for the absence of a visible stalk. As Dr. Coker states in correspondence, "this condition can be guessed as due to a sudden drought which caught the plants before they had finished their growth". But it is as yet a problem why this condition prevails only in this species and not in *T. australianum* which is also a common plant and frequents nearly always the same habitat. And again these plants even when mature have not been seen to open by an apical mouth as in *T. egranulosum*.

12. **Tylostoma adhaerens** Lloyd Myc. Writ. 7: 1199, 1923

Peridium globose upto 0·7 cm. in diameter, 0·6 cm. in height. Exoperidium a sandy case strongly adherent to the endoperidium.

Endoperidium opening by an irregular, naked, projecting, elongated mouth.

Stipe 0·3 cm. long, 0·25 cm. thick, dirty white, striate, stuffed.

Gleba pale, ferruginous; capillitium of branched threads, hyaline septate, uniform thread, slightly or strongly swollen at the nodes, the free ends rounded and slightly swollen, septa transverse or oblique. Spores globose or sub-globose, some irregular, pale yellow epispore medium, closely and finely verrucose, 4·8 to 5·5μ in diameter.

Sangla Hill. Solitary on the ground. (Plate II, Fig. 11)

The species was so determined by Dr. Coker and is characterized by strongly adhering exoperidium, finely verrucose spores, and an irregular elongated mouth.

A collection from *Gurdaspur* closely resembles the above but differs in having definitely smooth spores. Another collection from *Sangla Hill*, consisting of a single specimen resembles *T. adhaerens* in all particulars, but the spores are strongly echinulate; so it is regarded as a form of this species for the present, until some more material is available to reach some definite conclusion.

13. **Tylostoma volvulatum** Borsch. in Sorokine: Revue Myc. Pl. 98, 1890.

Syn. *T. tortuosum* Ehrenb.

Peridium globose or depressed globose, upto 2·25 cm. diameter, 1·15 cm. high. Exoperidium a sandy coat, completely falling away or remaining attached at places. Endoperidium dirty white, tough membranous, opening by a definite irregular aperture. In some specimens occasionally as many as three or four apertures are formed.

Stipe upto 12 cm. long from 0·6 to 0·8 cm. thick, occasionally with large caducous scales, but generally only striate, stuffed, with a very well developed volva at the base.

Gleba reddish brown; capillitium coloured, threads branched, septate, septa slightly swollen. Spores globose, spherical and some ellipsoidal, colour sub-hyaline to slightly yellowish, epispore medium, smooth, 3·7 to 5·2μ in diameter, mean 4·7μ.

Sangla Hill; Sargodha. Solitary in sandy soil. (Plate I, Fig. 4)

The plant is characterized by its larger size and a thick well developed volva at the base of the stem. No other *Tylostoma* compares with it as to size, excepting *Tylostoma laceratum* with which it is frequently found growing but the

latter is easily distinguished by its manner of dehiscence and the dark reddish colour of the peridium.

14. **Tylostoma laceratum** (Ehrenb.) Fries Syst. Myc. 3: 44, 1829.

Syn. *Schizostoma laceratum* Ehrenb.; *Tylostoma Schweinfurthii* Bres.; *T. Karnbackii.*

Peridium globose or depressed globose, upto 2·4 cm. diameter and 2 cm. high. Exoperidium a sandy coat completely falling away leaving the smooth endoperidium exposed. Endoperidium membranous of brownish colour rupturing along definite lines to expose the gleba. (Lloyd states that the upper portion of the peridium breaks away in pieces and does not open by a definite mouth). The writer finds that the peridium ruptures along definite lines which are marked in the unopened specimens by lighter colour, and thus forming definite valves which remain intact even when the gleba is dispersed. In some specimens the endoperidium opens along the lines mentioned above even when the top portion has not broken at all.

Stipe upto 16 cm. long and upto 1·6 cm. thick, longitudinally striate and tortuose, stuffed, with remains of the volva at the base.

Gleba of rich brown colour; capillitium long, tortuose, intertwined, deeply coloured and sparingly branched, without any septa, twice the thickness of the spores. Spores spherical to globose, brownish, epispore medium, smooth, 5·2 to 6·1μ in diameter, averaging 5·7μ.

Sangla Hill; Sargodha. Solitary in sandy soil. Plate I, (Fig. 5 & 5a) and (Plate II, Fig. 1) Occasionally 2 or 3 specimens are found united by their stalks.

It is characterized by its method of dehiscence and the rich brown colour of the gleba. According to Lloyd the spores are finely warted but in our plants the spores are perfectly smooth, even under the oil immersion. The "universal veil" or volva which was doubtfully regarded by Lloyd to be present in the plant is found to be very well developed. Sometimes characteristic outgrowths are found at the base of the peridium.

Tylostoma laceratum Var. nigrum S. Ahmed, Var. Nov.

Plants resemble the above in the manner of dehiscence but strongly differ in the smaller size and black colour of the gleba. Spores ellipsoidal to globose, light chocolate brown, epispore medium thick, smooth, 4·3 to 5·9μ in diameter; mean 5·5μ.

Sangla Hill. In sandy soil. (Plate II, Fig. 9)

It is as yet unsettled whether to call this plant a *Tylostoma* or *Schizostoma*. Although it is classified here as a species of

Tylostoma, the writer is of the opinion that it should be better classed as a separate genus, *Schizostoma*. The method of dehiscence is remarkable and there is no suggestion of anything like it in any species of *Tylostoma*.

Acknowledgements

The writer wishes to express his gratitude to Dr. B. B. Mundkur of the Imperial Agricultural Research Institute, New Delhi, for placing all literature from his personal library at the writer's disposal, for the help rendered in measuring the spores and in writing up of this paper.

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References

1. BUTLER, E. J. and BISBY, G. R.—(1931). Fungi of India, Imp. Counc. Agric. Res. Sci. Mono. 1, New Delhi.
2. COKER, W. C. and COUCH, J. N.—(1928). The Gasteromycetes of the Eastern United States and Canada. Chapel Hill, U.S.A.
3. CUNNINGHAM, G. H.—(1925). Proc. Linn. Soc. N. S. Wales, 50: 367-373.
4. ———(1932). Proc. Linn. Soc. N. S. Wales, 57: 27-39.
5. FISCHER, Ed.—(1933). Gasteromycetae. In Engler and Prantle, Die Naturlichen Pflanzen-familien, 2ed. 7a. Leipzig.
6. FISCHER, Ed.—(1936). Berichte der Schweiz. Botan. Gessellschaft. 45: 231-247.
7. Lloyd, C. G.—(1906). The Tylostomeae, Cincinnati, U.S.A.
8. MORSE, E. E.—(1933). Mycologia, 25:1-33.
9. WHITE, V. S.—(1901). Bull. Torrey. Bot. Club, 28:421-441.

Explanation of Plates

PLATE II.

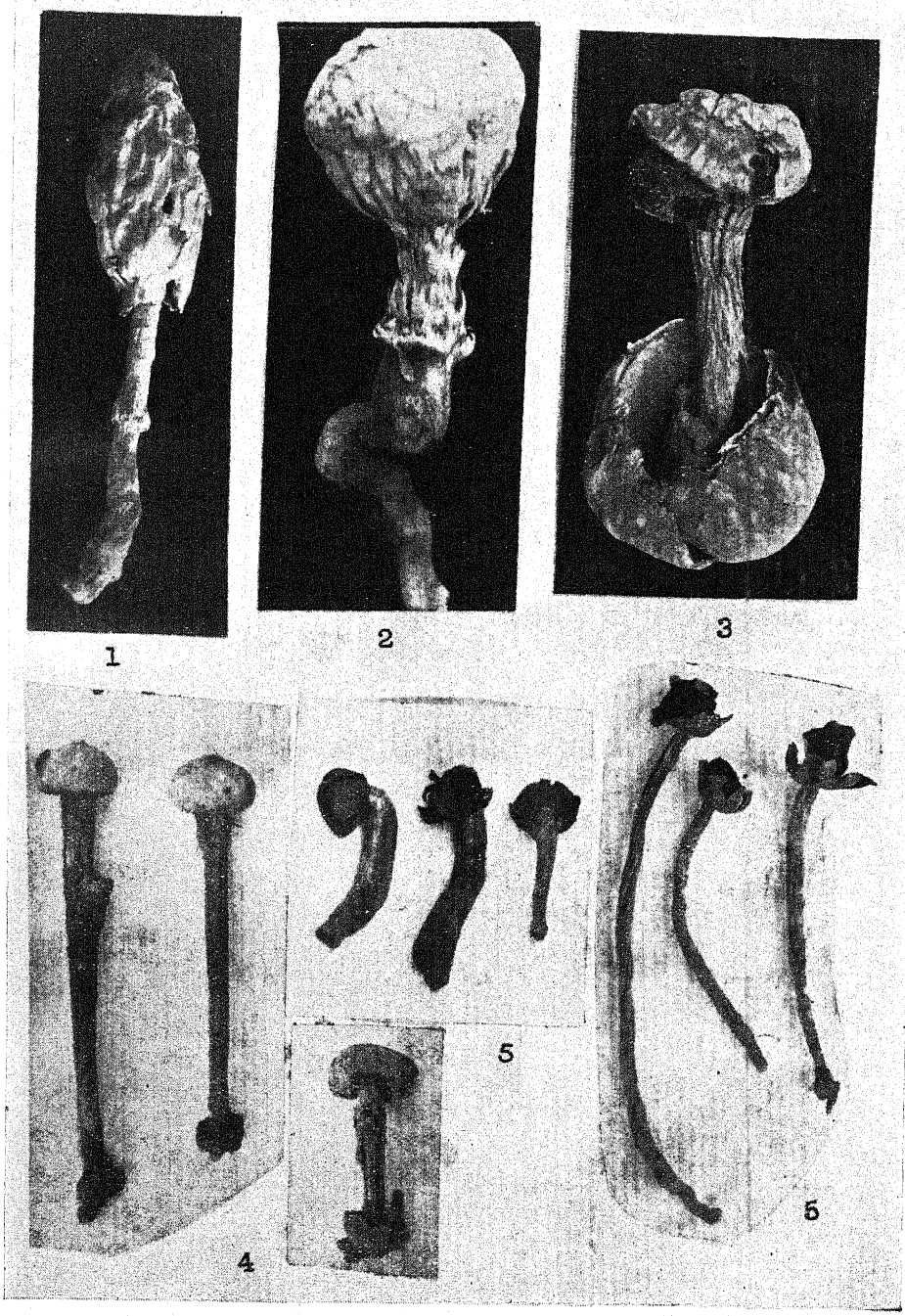
($\frac{1}{2}$ nat. size.)

Fig. 1.—*Podaxon pistillaris.*
Fig. 2.—*Phellorina inquinans.*
Fig. 3.—*Battarrea Stevenii.*
Fig. 4.—*Tylostoma volvulatum* (3 plants).
Fig. 5.—*Tylostoma laceratum.*
Fig. 5a—*Tylostoma laceratum.*

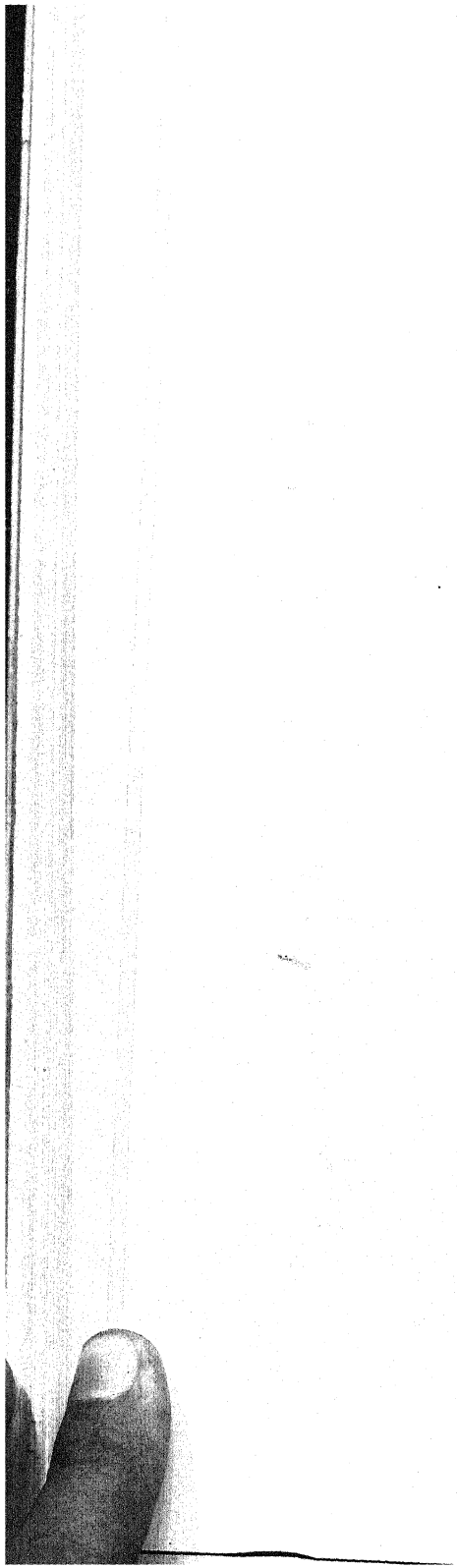
PLATE III.

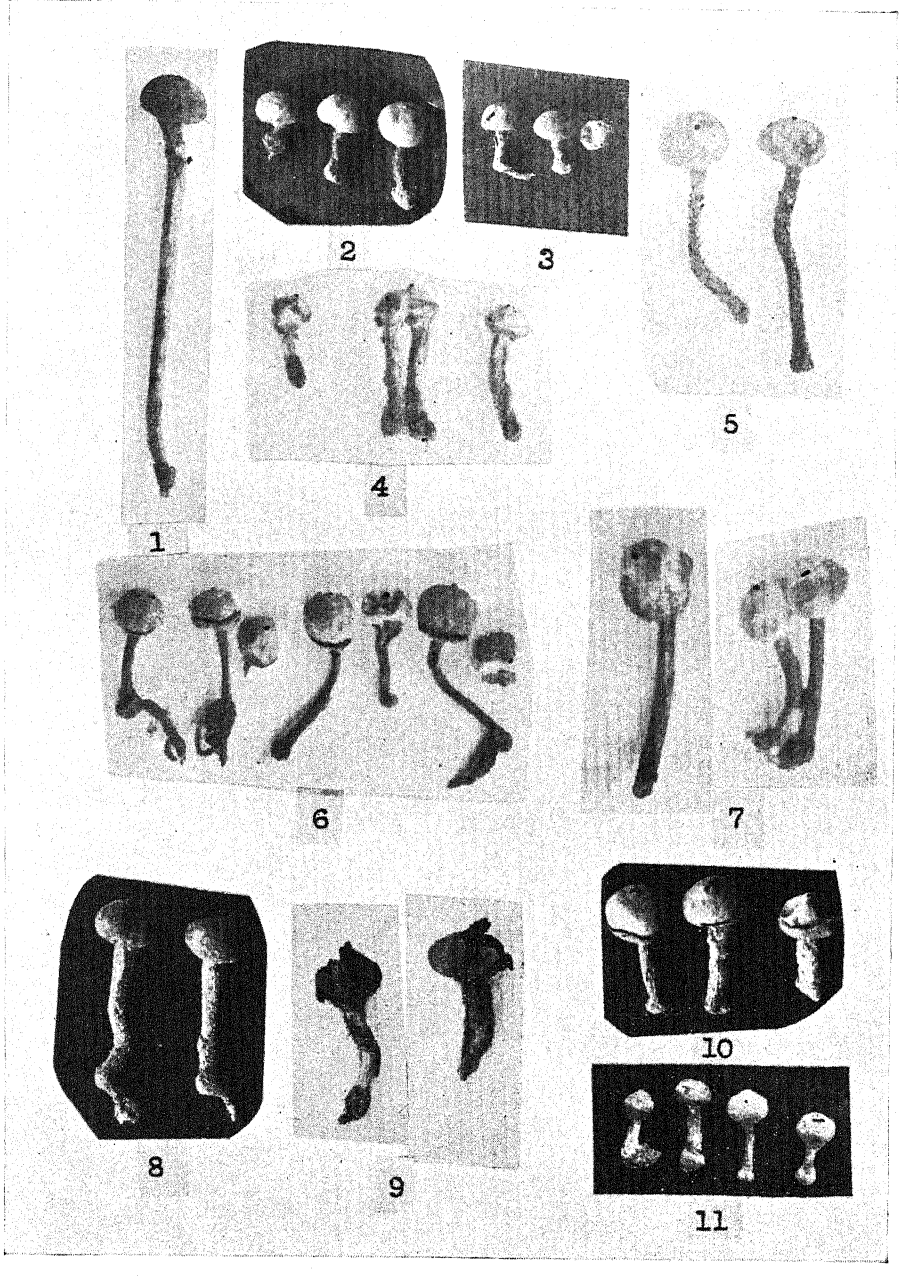
All natural size, excepting No. 1, which is ½ nat.

Fig. 1.—*Tylostoma laceratum*. Unexpanded plant.
Fig. 2.—*Tylostoma verrucosum*
Fig. 3.—*Tylostoma occidentale*.
Fig. 4.—*Tylostoma mammosum*.
Fig. 5.—*Tylostoma squamosum*.
Fig. 6.—*Tylostoma pygmaeum*.
Fig. 7.—*Tylostoma Macalpinianum*.
Fig. 8.—*Tylostoma australianum*.
Fig. 9.—*Tylostoma laceratum* var. *nigrum*.
Fig. 10.—*Tylostoma egranulosum*.
Fig. 11.—*Tylostoma adhaerens*.



SULTAN AHMAD—*GASTEROMYCETEAE*





SULTAN AHMAD—*GASTEROMYCETEAE*

AN EXAMPLE OF A NAKED OVULE IN *GALPHIMIA GRACILIS*

BY

A. N. FOTIDAR, M. Sc.*

Communicated by A. C. Joshi, Benares Hindu University

Received on 23rd June, 1939

Galphimia gracilis Bartl., a shrub belonging to the family Malpighiaceae, is occasionally cultivated in gardens at Benares. It produces handsome bunches of yellow flowers during the summer. The flowers possess a gynaecium of three carpels and the trilocular ovary shows a single pendulous ovule in each loculus. While studying the embryology and cytology of the plant, the writer came across one ovule borne by a carpel outside its ovary. As the number of such naked ovules described in the literature on vegetable teratology is rather small, the writer takes this opportunity of putting it on record.

Before proceeding to describe the naked ovule, it is desirable to devote a little space to the nomenclature of such ovules, as there seems to have been some confusion about it. Some authors (Raunkiaer, 1914; etc.) have called such ovules as "Gymnospermous ovules". Such a name, as Bambacioni-Mezzetti (1937) has also pointed out, is somewhat inappropriate. The naked ovules observed among angiosperms are generally never found to develop into seeds. It is, therefore, better to describe them merely as "Naked" or "Gymno-ovules," rather than "Gymno-spermous ovules". The only exception observed is in *Vitis vinifera* var. *Mourvedre*, where Baranov (1927) observed, besides pistils with naked ovules, also a berry with protruding seeds. In such a case only the name "Gymnospermous ovules" is appropriate.

Coming to the naked ovules observed so far we can place them into three types. First there is the case described recently by Abraham (1934) in cotton, where the naked ovule was borne on a receptacular prolongation of the floral axis. It had no connection at all with the carpels of the flower.

In the second type may be placed those cases where the ovules become naked due to the opening out of the carpels and the lack of fusion of their margins. An old example of this type of naked ovules is seen in *Sassafras*. Baillon (1870) observed that in many samples of *Sassafras officinale* growing in the forest of Buologne, the pistil was anomalous in as much as the carpel was

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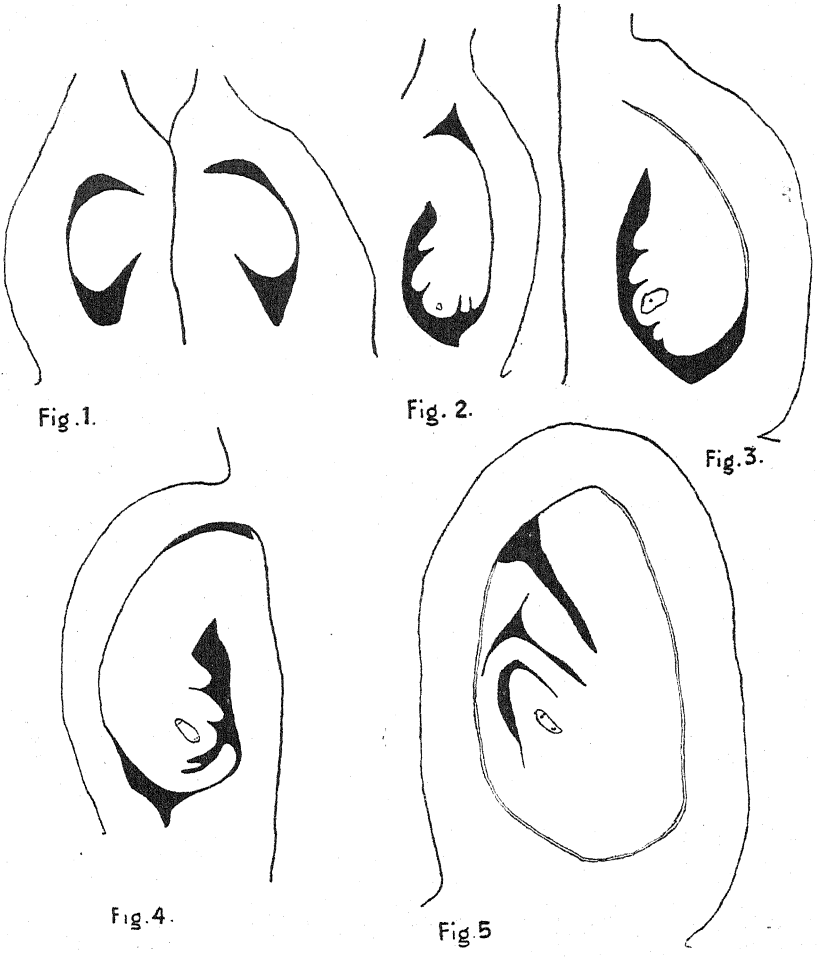
open, and the more or less normal ovule was placed either in front of it on a small axis situated in the depth of the fissure or on one of its margins. Other plants in which examples of this type of naked ovules have been observed are *Begonia semperflorens* var. *gigantea* (Dümmer, 1912), *Lychnis dioica* (Snow, 1923) and *Beta vulgaris* (Archimovitch, 1931). The examples of naked ovules in the family Ulmaceae described by Finn (1935) in *Zelkowa crenata*, Leliveld (1935) in a species of *Ulmus*, and Kapoor (1937) in the Indian tree *Holoptelea integrifolia* also fall in this class, though they differ in a few details. The gynaecium here does not completely open out, but the stylar canal never completely closes. It remains open and the ovules project out by their long funicles. These example serve to connect the second and third types. It may also be noted that in many of these cases the ovules which are anatropous, when they are borne inside the ovary, become atropous when they are found freely exposed.

In the third type we can place those naked ovules in which the carpel is found to be closed in the mature condition and the naked ovules are borne outside the ovary. Here may be mentioned the examples of naked ovules observed by Raunkiaer (1914) in *Knowltonia vesicatoria* and by Bambacioni-Mezzetti (1937) in *Persea gratissima*. Raunkiaer found in a sample of the Ranunculaceous plant from South Africa brought up in the green house of the Botanical Garden in Copenhagen numerous ovaries with a free ovule placed at the base of the style. Bambacioni-Mezzetti found a very large number of nude ovules, about 50% of the total, in nearly the same position on a tree of *Persea gratissima* in the Botanical garden at Rome. They had become naked by an anomalous growth of the funicle, which instead of being bent downwards, as happens in normal pistils with a single hanging ovule, was bent upwards and the ovule had passed out through the stylar canal at an early stage of development.

The example of the naked ovule discovered by the writer in *Galphimia gracilis* Bartl. falls into the third class described above. The ovule was found above the ovary of a carpel. It was seen to arise from the base of one of the styles (Fig. 6). The ovary of the carpel on which it was borne was quite empty and not so well developed as that of others. This shows that the naked ovule really belonged to the ovary of this carpel. Only it had come out and shifted its position close to the base of the style. In other respects the naked ovule was quite normal, differing only a little in the greater development of the funicle. It had two integuments and the embryo-sac like the normal ovules. The abnormal development of the funicle may have been due to the extra space available for growth.

As regards the cause of development of naked ovules we find many explanations. Abraham (1934) suggests that in

cotton it may be due to a genetic disturbance arising from hybridisation. Baranov (1927) thinks that in *Vitis vinifera* naked ovules arise as a result of vegetative mutation. Finn (1935) attributes this phenomenon in *Zelkowa crenata* to injuries by insect parasites. Bambacioni-Mezzeti (1937) suggests positive aerotropism to be the cause of development of naked ovules in *Persea gratissima*. Many examples of naked ovules in the literature, where the condition is the result of opening out of the carpels, have been vaguely described as reversions.



Figs. 1-5. *Galphimia gracilis*. Longitudinal sections of carpels of various ages showing the development of the ovule. × 156.

The naked ovule described here in *Galphimia gracilis* appears to be merely an abnormality of development. If the development of ovules is studied in this plant (Fig. 1-5), it is found that the ovules arise as papillae from the axile placentas. They grow straight till they meet the opposing dorsal wall of the carpel and then turn downwards as a result of the obstruction that they meet, as happens in *Medicago*, etc. (Joshi, 1935). It appears that in the case of the naked ovule, the ovule primordium had turned upwards as a result of this obstruction and come out of the carpel at an early stage of development.

In conclusion, it is my pleasant duty to tender my sincere thanks to Dr. A.C. Joshi for his help in the preparation of this note. My thanks are also due to Dr. P.N. Roy of the Department of Modern European Languages for help in translating some of the literature cited in this paper.

Literature Cited

ABRAHAM, P. (1934).—Occurrence of extracarpellary ovules on the floral axis in cotton. *Jour. Ind. Bot. Soc.*, 14, p. 291.

ARCHIMOVITCH, A. (1931).—On the inbreeding method applied to the sugar-beet. *Trans. Belaja Tzerken St.*, 6.

BAILLON, H. (1868-1870).—Sur des fleurs monstrueuses de *Sassafras officinale*. *Adansonia*, 9, p. 380.

BAMBACIONI-MEZZETTI, V. (1937).—Gimnoovulia in *Persea gratissima* Gaertn. e considerazioni sulla monomeria del pistillo di questa pianta. *Ann. Bot., Roma*, 21, p. 1.

BARANOV, P. (1927).—Zur Morphologie und Embryologie der Weinrebe. *Ber. Deutsch. Bot. Ges.*, 45, p. 97.

CAPOOR, S. P. (1937).—The life history of *Holoptelea integrifolia*. *Beih. Bot. Centralbl.* 57, p. 233.

DÜMMER, R. A. (1912).—A bisexual "gymnospermous" Begonia. *Ann. Bot.*, 26, p. 1123.

FINN, W. (1935).—Ein Fall von eigenartiger " Nacktsamigkeit" bei Angiospermen. *Ber. Deutsch. Bot. Ges.*, 53, p. 178.

JOSHI, A. C. (1935).—Criticism of Dr. Thomas's recent hypothesis on the nature of the angiospermous carpel. *Jour. Bot.*, p. 286.

LELIVELD, J. A. (1935).—Cytological studies in the genus *Ulmus*. II. The embryo sac and seed development in the common Dutch Elm. *Rec. Trav. Bot. Neerl.*, 32, p. 543.

RAUNKIAER, C. (1914).—Gymnospermi hoo *Knowltonia vesicatoria*. *Botanisk Tidsk*, 33, p. 379.

SNOW, R. (1923).—An apocarpic plant of red campion (*Lychnis dioica* L.). *New Phyt.*, 22, p. 156.

Explanation of Plate IV.

Fig. 6.—*Galphimia gracilis*. Photomicrograph of the longitudinal section of an ovary showing the naked ovule. × 36.

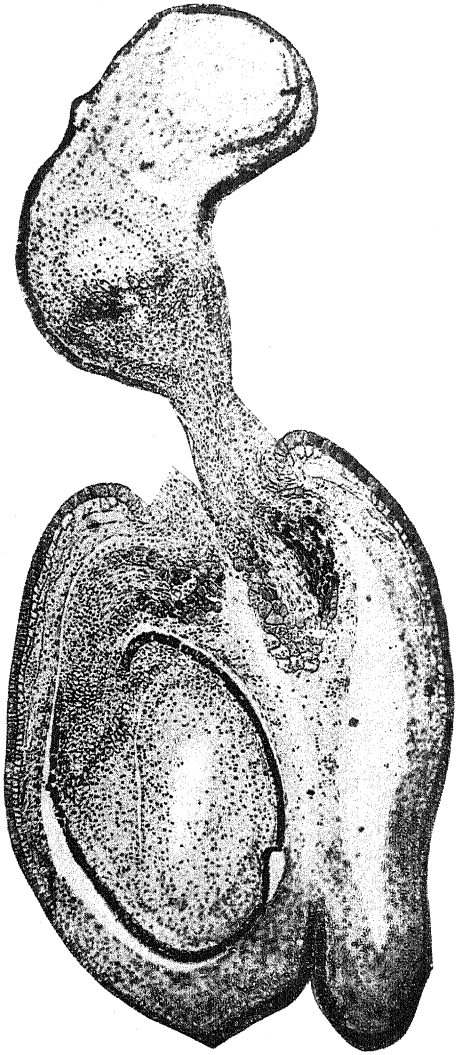
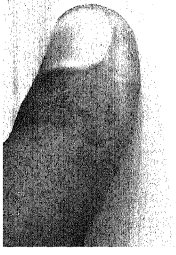


Fig. 6

A. N. FOTIDAR—*GALPHIMIA GRACILIS*



MARCH OF TRANSPIRATION OF A LEAF SINCE ITS MEASURABLE STAGE TO ITS FALL

BY

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Contents

Introduction

There has been considerable work on the transpiration of cut twigs or of entire plants by various workers, namely, the relation of transpiration to the water-content of the soil (8), the action of temperature and other environmental and internal factors on transpiration (2, 4, 7), the relation of transpiration with the stomatal apparatus (1, 3, 5), the behaviour of the transpiration curves for the whole day (2), and many other aspects of transpiration. But there has been no work as to how a leaf, attached to the plant all along, transpires from day to day till it falls off the plant. When the transpiration of a cut twig is taken, it is, surely, the transpiration of the disturbed organ of the plant. The transpiration of the whole plant, again, does not indicate the activity of individual leaves. When the leaf is attached to the plant, and the transpiration studied, then there is no disturbance in the organic connections of the plant and the leaf enjoys its natural position all along its life. Our attempt has been to find out the transpiratory activity of such a leaf from day to day while it is attached to the plant all along, *i.e.*, in our work we give the march of transpiration of a leaf since its measurable stage to its fall.

Material and Method

At first the problem was taken up with a view to understand how a leaf transpires from day to day when it is attached to the plant, while the plant is kept under natural conditions. But the results obtained from such an experiment necessitated the observation of the march of transpiration of a leaf, when the plant is kept under controlled conditions of humidity. Again, there had been the need of recording the march of transpiration of an evergreen leaf while the original work was conducted in deciduous leaves. So, our paper gives an account of the march of transpiration of deciduous leaves when the plants are kept under natural conditions and controlled conditions of humidity, and the march of transpiration of an evergreen leaf when the plant is kept under controlled conditions of humidity.

The deciduous plants used are (1) *Datura alba* and (2) *Helianthus annuus*. The evergreen plant is *Ixora undulata*, whose leaves last for three years at Cuttack.

First of all work is done in a leaf of *Helianthus annuus*. A special leaf-chamber is constructed to enclose the experimental leaf. The chamber is sufficiently big to hold a full grown Sunflower leaf or a Datura leaf. This chamber has two glass faces held by means of a metal frame. There is one inlet and an outlet on this frame. One side of this frame is so constructed that it can be closed air-tight by screwing down two sliding pieces. These sliding pieces have got rubber pads on their inner faces and where these two pieces touch each other there is a space left for the introduction of a piece of cork. The sliding pieces are taken out and the experimental leaf is introduced into the chamber, then a piece of rubber cork, which is split longitudinally, is put round the petiole of the leaf and then the sliding pieces are replaced and held tight against each other and against the chamber by being screwed tightly. By this operation the chamber becomes air tight. If there be leakage that can be stopped by means of plasticine. In this way the leaf is kept inside the leaf chamber.

The inlet tube of the chamber is connected to a series of U tubes packed up with $CaCl_2$, which again is connected to a Woulfe's bottle containing strong H_2SO_4. The outlet tube is attached to a series of weighed $CaCl_2$ tubes, which are connected to an electrical aspirator. So, when the aspirator is in operation, a current of air is drawn through the H_2SO_4 bottle, the U tubes containing $CaCl_2$, the leaf chamber and the series of small $CaCl_2$ tubes. As this current of air passes through H_2SO_4 and $CaCl_2$ it gets completely free from moisture. This dry air then passes into the leaf chamber and gets moist by the moisture given off by transpiration. As this passes through the series of $CaCl_2$ tubes, the moisture is absorbed by $CaCl_2$. The weight of the

$CaCl_2$ tubes is known before they are connected, and after transpiration, they are again weighed. The difference of weight gives the amount of moisture transpired by the leaf. The current of air is drawn during the day as well as during the night through the leaf-chamber at a constant rate. Only at a definite period of the day, *i.e.*, from 11-30 A.M. to 2-30 P.M., the moisture transpired by the experimental leaf is allowed to be absorbed by weighed $CaCl_2$ tubes. The amount of moisture is determined afterwards by weighing these tubes. From day to day the area of the leaf is traced out from the glass face of the chamber by means of a transparent paper and the transpiration per sq. cm. is determined. When the $CaCl_2$ tubes are put in to the arrangement at 11-30 A.M. and when they are detached at 2-30 P.M., the humidity and the temperature of the surroundings are taken and recorded.

For controlled conditions of humidity a potted plant is kept inside a glazed chamber sufficiently spacious to hold the plant and the apparatus, excepting the electrical aspirator. The chamber is connected to the outside atmosphere. The soil-surface of the pot containing the plant is covered up by means of a paraffined paper in order to prevent moisture evaporating into the chamber and water is supplied to the plant through an earthenware tube planted to the soil of the pot. Inside the transpiration chamber some rock salt with some water is kept, so that humidity can be kept fairly constant (varying within 7%).

Both under natural conditions and controlled conditions of humidity, the transpiration of a leaf from its measurable stage to its fall is recorded. In case of *Helianthus* these records begin when the leaf is ten days old and in case of *Datura*, when it is eight days old. In both the cases, the life is a month and a half long, so that transpiration records, in each case of these deciduous leaves, are kept for 35 days.

The march of transpiration of *Ixora undulata* is recorded for 2 months (62 days) beginning from the eighth day of its age, the plant being kept under controlled conditions of humidity.

When the plants are kept under controlled conditions of humidity, all other environmental factors remain as natural as possible.

Together with the transpiratory records the number of stomata per unit area at different stages of development of the leaves of *Datura* is counted in order to examine the transpiratory results of the leaves.

Results

The results obtained are represented by means of graphs and tables. The tables are given in the appendices.

The transpiratory rates are represented in mgs. of moisture per unit area (1 sq. cm.) for three hours.

It is seen that in the deciduous leaves (appendices 1 & 2) the transpiration rate per unit area rises with age, then falls to a steady value and ultimately declines. In *Helianthus* the life cycle of the leaf is completed in 43 days, while in *Datura* it is 40 days. The steady value is attained in *Helianthus* in 19 days and is maintained for 19 days, after which the decline sets in (Fig. 1). In the case of *Datura* the steady value occurs after 18 days and is maintained for 17 days, after which the decline sets in and is completed in 5 days. This happens under natural conditions (Fig. 2). Under controlled conditions of humidity the decline period is 4 days (appendix 3) and is not so steep as is the case under natural conditions (Fig. 3).

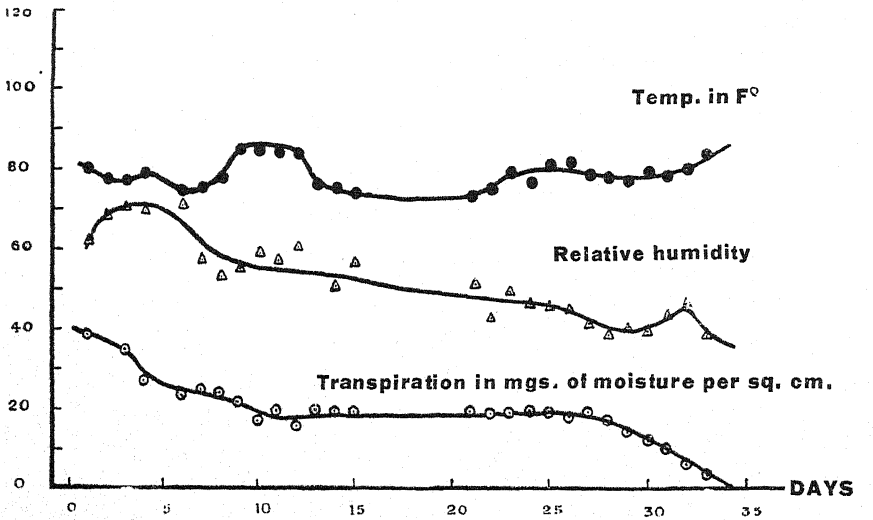


Fig. 1.—Showing the curve of transpiration of *Helianthus annuus* leaf in mgs. of moisture per sq. cm. for 3 hours since the 10th day of its age to its fall under natural conditions, (lowermost curve) together with the curves (middle and the top curves respectively) of mean relative humidity in percentages (mean between the values observed in the beginning and end of experiment each day) and mean temperature in F° (mean between the values observed in the beginning and end of experiment each day) of the surrounding on corresponding days.

Whatever that may be, the period of steady value seems to bear a certain ratio (nearly half the life period) to the life cycle of the leaf. With a view to see whether the period of steady value would be maintained for a longer period in evergreen leaves, the transpiration of *Ixora undulata* is measured for 62 days. The steady phase is attained in 26 days and is maintained for 36 days, when the experiment is discontinued Fig. 4 (appendix 4). Thus it is seen that the steady value

depends on the length of the life of the leaf. Longer the life of the leaf, longer is the steady phase.

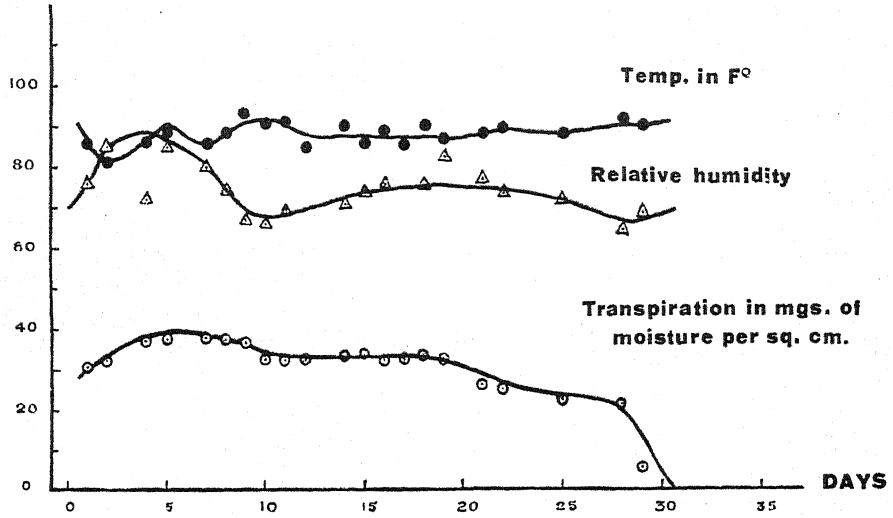


Fig. 2.—Showing the curve of transpiration of *Datura alba* leaf in mgs. of moisture per sq. cm. for 3 hours since the 8th day of its age to its fall under natural conditions (lowermost curve) together with the curves (middle and top curves respectively) of mean relative humidity in percentages (mean between the values observed in the beginning and end of experiment each day) and mean temperature in F° (mean between the values observed in the beginning and end of experiment each day) of the surrounding on corresponding days.

Again, another interesting point is seen from the results. It is seen that the curve of transpiration of the experimental leaf, (Figs. 1-2) when the plant is kept under natural conditions seems very irregular, even though the characteristic rise and then a fall to steady value is quite clear. When attention is given to the curve of environmental humidity, it is seen that the transpiration curve more or less reflects the characteristics of the curve of environmental humidity. When we turn to the curve of transpiration of the leaf, (Fig. 3) when the plant is kept under controlled conditions of humidity, the transpiration curve seems much regular.

Besides these, there seems a relationship of the number of stomata per unit area with age with the transpiration curve. We find that at the early stage the number of stomata per unit area is great, but later with age it falls to a steady value Fig. V (appendix 5).

DISCUSSION.

From these results we find that in every case there is that characteristic curve, starting with a rise in transpiration which falls to a steady value and then declines. The steady

value seems to bear a certain relation with the life-cycle of the leaves, ($\frac{1}{2}$ nearly, in the case of deciduous leaves). The longer the life period of a leaf the longer is this steady phase. The initial rise of this transpiration curve may be ascribed to greater number of stomata, cuticular transpiration and higher respiratory activity which cease later on.

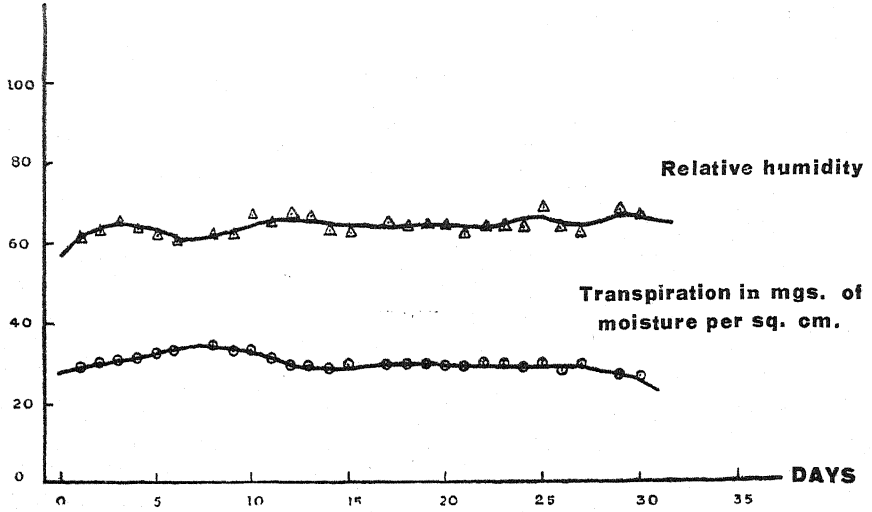


Fig. 3.—Showing the curve (lower curve) of transpiration of *Datura alba* leaf in mgs. of moisture per sq. cm. for 3 hours since the 8th day of its age to its fall, under controlled conditions of humidity together with the curve (upper curve) of mean values of controlled relative humidity in percentages (mean between the values in the beginning and end of experiment each day) on corresponding days.

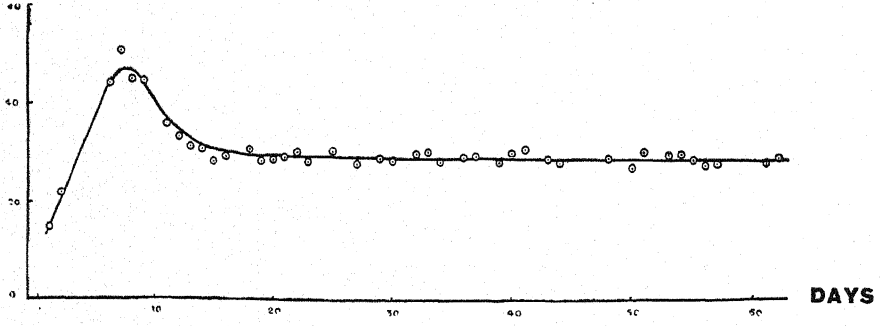


Fig. 4.—Showing the transpiration curve of *Ixora undulata* leaf, in mgs. of moisture per sq. cm. for 3 hours since the 10th day of its age to its fall under controlled conditions of humidity.

We then come to the next point, namely the irregular transpiration curve under natural conditions and regular ones

under controlled conditions. In both the cases the ups and downs in the transpiration curve seem to correspond with those of the curve of humidity of the surroundings of the plants. When the leaf is enclosed in a chamber, one would have expected that the curve of transpiration would not show any correlation with changes in humidity, in the air surrounding the plant ; but contrary to this expectation, transpiration of the experimental leaf shows fluctuations correlated with changes in humidity outside. The experimental leaf is enclosed in the leaf chamber, through which only dry air is passing, so that the air surrounding it has nearly 0% of humidity. As the experimental leaf is under constant humidity, and as the transpiration of the experimental leaf seems to rise and fall with the rise and fall of humidity of the air surrounding the plant, it can be said that the environmental humidity influences the transpiration of the experimental leaf some how or other acting through the other leaves. This indicates how all the leaves of the plants are linked together into an organic whole. Similar phenomenon depicting the influence of one another amongst a multitude of leaves in the plant, has been described by Famintsin (6). Ball, (6) also records a similar case with regard to the cotton plant in Egypt.

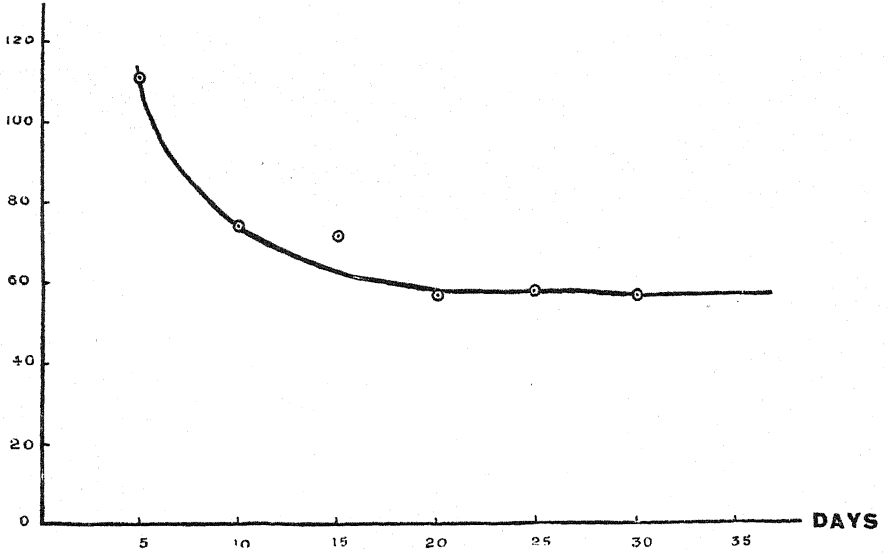


Fig. 5.—Curve showing the mean value of the number of stomata on both the surfaces per unit area at different stages of development of *Datura alba* leaf.

So in the end we conclude that the investigations have shown two important points. (1) There is a characteristic curve

of transpiration for each leaf with a rise, then a fall to a steady value and finally a decline.

(2) All the leaves of a plant are connected into an organic whole, so that they influence each other, in their activities specially transpiration.

Summary

The march of transpiration of two deciduous leaves has been found out. When the leaf becomes sufficiently big for experimentation, it is introduced into the leaf-chamber while it is attached to the plant and a current of dry air passes through the chamber till the leaf falls off the plant in due course. The moisture transpired by the leaf is found out from day to day for a definite period on each day.

It is seen that the transpiration of the leaf rises first and then falls to a steady value, after which it declines. In the case of an evergreen leaf the steady phase of transpiration is much longer.

It is also found that the environmental humidity affects the transpiration of the experimental leaf influencing through the other leaves of the plant. This shows that all the leaves of a plant are linked together into an organic whole.

References

1. DARWIN, F.—On the relation between transpiration and stomatal aperture.
Phil. Trans. Roy. Soc., B. Vol. CCVII. 1916.

2. INAMDAR, R. S. AND DABRAL, B. M.—Experiments on transpiration. (1) Daily water balance of plants in arid regions.
Jour. Ind. Bot. Soc. Vol. 9, Page 1, 1930.

3. Knight, R. C.—Further observations on the transpiration, stomata, leaf-water-content, and wilting of plants.
Annals of Bot., Vol. 36, Page 361, 1922.

4. LIVINGSTON, B. E. AND BROWN, W. H.—The relation of the march of transpiration to variations of water-content of foliage leaves.
Bot. Gaz. Vol. 53, Page 309, 1912.

5. LLOYD, F. E.—Physiology of stomata, Cornegie. Inst. pub. Washington, No. 89, 1908.

6. MAXIMOV, N. A.—The plant in relation to water. (Edited by R. H. Yapp, 1929) Page 121.

7. SHREVE, E. B.—Factors governing seasonal changes in transpiration of *Eucelia farinosa*.
Bot. Gaz. Vol. 77, Page 432, 1924.

8. SINGH, B. N., SINGH, R. B. AND SINGH, K.—Investigations into the water-requirements of crop plants.
Proc. Ind. Ac. Sci. Vol. 1, Page 471, 1935.

APPENDIX I

Transpiration in *Helianthus annuus* leaf since the 10th day of its age under natural conditions.

Days.	Transpiration per unit area in mgs. per 3 hours.	Humidity in the beginning of observation in percentages.	Humidity at the end of observation in percentages.	Temperature in F° at the beginning of observation.	Temperature at the end of observation.
1	38·5	58	66	80	80
2	65·5	63	74	76·5	79
3	34·3	67	74	76	78
4	27	65	74	78	80
5	..	..	..	..	..
6	23·3	71	71	74	75
7	25	51·75	62·5	75	75
8	24	53	53	77	78
9	21·4	51	60	85	84
10	17·1	57	61	84	85
11	19·3	57	58	84	84
12	16	63	58	83	84
13	19·2	73	82	76	76
14	19·4	48·5	51·75	75	75
15	19·3	54·5	58·5	73	74
16	..	..	..	..	..
17	..	..	..	..	..
18	..	..	..	..	..
19	..	..	..	..	..
20	..	..	..	..	..
21	19·34	48	54·5	73	73
22	19	43	42·5	76	73
23	19·09	58·75	40	75	82
24	19·7	55	38·5	75	77
25	19·45	50	40·5	79	82
26	18	44	44·75	79	83
27	19·34	43	39	76	80
28	17·2	41·5	36	76	79
29	14·2	44	36	74	79
30	12·7	43·5	35	77	81
31	10·3	46	41·5	76	80
32	6·3	55	38·5	75	84
33	4	45	32	81	84

APPENDIX II

Transpiration of *Datura alba* leaf since the 8th day of its age under natural conditions.

Days.	Transpiration per unit area in mgs. per 3 hours.	Humidity in the beginning of observation in percentages.	Humidity at the end of observation in percentages.	Temperature in F° at the beginning of observation.	Temperature at the end of observation.
1	30·5	80	72	86	85
2	33·2	83	87	81	82
3	..	..	..	..	..
4	37·3	72	72	85	87
5	37·5	80	92	89	87
6	..	..	..	..	..
7	38	91	69	83	89
8	37·2	70	80	90	87
9	36·5	64	71	92	93
10	32·8	66	67	90	92
11	32·5	73	67	90	93
12	32·7	84	87	87	83
13	..	..	..	..	..
14	33·1	73	70	90	91
15	33·8	87	73	83	90
16	32·3	73	81	89	90
17	32·3	92	84	86	86
18	33 5	72	81	92	90
19	32·3	84	84	87	88
20	..	..	..	..	..
21	26·8	77	80	89	89
22	25·1	73	77	90	90
23	..	..	..	..	..
24	..	..	..	..	..
25	22·6	73	73	88	90
26	..	..	..	..	..
27	..	..	..	..	..
28	21·5	67	64	92	93
29	6	73	67	90	92

APPENDIX III

Transpiration of *Datura alba* leaf since the 8th day of its age under controlled conditions of humidity.

Days	Transpiration per unit area in mgs. per 3 hours.	Humidity in the beginning of observation in percentages.	Humidity at the end of observation in percentages.	Temperature in F° at the beginning of observation.	Temperature at the end of observation.
1	29	62	61	97	97·5
2	30	63	63	98	98
3	30·8	66	65	98	99
4	31·2	65	62	96	95·5
5	32·2	63	60	98	99
6	33	61	60	99	98
7	..	..	..	..	..
8	34	63	61	99	99
9	33·2	60	64	99	98·5
10	33	65	69	99	97
11	31·5	66	64	98	98·5
12	29·2	66	69	99	98
13	29·5	64	69	98·5	98
14	28·9	62	64	97	97·5
15	29·7	63	63	98	98
16	..	..	..	..	..
17	29·6	66	65	99	99
18	29·7	66	62	98	99·5
19	29·2	66	63	99	99
20	29·4	63	64	99	99
21	29·1	62	61	97	97·5
22	29·7	63	64	98	98·5
23	29·2	64	63	98·5	98
24	28·6	63	63	99	98·5
25	29	69	67	97	97·5
26	27·6	63	63	99	99
27	29·3	63	61	99	99
28	..	..	..	..	..
29	27	68	67	96	96·5
30	26·3	65	67	97	97

APPENDIX IV

Transpiration in *Ixora undulata* leaf since the 10th day of its age under controlled condition of humidity.

Days.	Transpiration per unit area in mgs. per 3 hours.	Humidity in the beginning of observation in percentages.	Humidity at the end of observation in percentages.
1	15	64	64
2	22	63	64
3	..	..	..
4	..	..	..
5	..	..	..
6	47	62	65
7	51	63	66
8	45·2	63	65
9	45	64	65
10	..	..	..
11	36·5	66	66
12	34	63	63
13	32	64	65
14	31·5	65	66
15	29	61	64
16	30	62	63
17	..	..	..
18	31·5	62	63
19	29·2	65	63
20	29·3	63	63
21	30	65	66
22	31	64	67
23	29	66	65
24	..	..	..
25	31·2	62	67
26	..	..	..
27	28·9	65	66
28	..	..	..
29	30	64	64
30	29·6	63	64
31	..	..	..
32	31	62	63
33	31·6	61	65
34	29·8	65	67
35	..	..	..
36	30·5	64	64
37	30·6	64	65
38	..	..	..
39	29·6	62	64
40	31·3	63	61
41	32	63	62
42	..	..	..
43	30·3	61	63
44	29·7	63	63
45	..	..	..

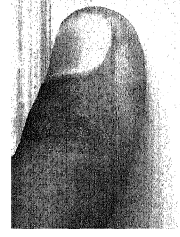
APPENDIX IV—(*contd.*)

Days.	Transpiration per unit area in mgs. per 3 hours.	Humidity in the beginning of observation. in percentages.	Humidity at the end of observation in percentages.
46	..	..	..
47	..	..	..
48	30·8	62	64
49	..	..	..
50	29	62	62
51	32	61	62
52	..	..	..
53	31·5	63	63
54	31·8	62	63
55	30·6	61	61
56	29·6	64	63
57	30·5	61	61
58	..	..	..
59	..	..	..
60	..	..	..
61	30·2	61	62
62	31·4	61	64

APPENDIX V

Mean value of the number of stomata per O. 128sq. mm. on both the surfaces of *Datura alba* leaf with age.

Age in Days.	Number of Stomata on Upper surface per unit area.	Number of Stomata on Lower surface per unit area.	Total.
5	59·7	51·3	111
10	41·2	32·8	74
15	40·5	31·4	71·9
20	31·5	24·6	56·1
25	32·1	25·2	57·3
30	31·7	24·6	56·3



A CONTRIBUTION TO THE EMBRYOLOGY OF THE APONOGETONACEAE

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Aponogetonaceae is a small family of the Helobiales, comprising only one genus *Aponogeton*. There are about 40 species, distributed over Africa, tropical Asia and Australia. They are most abundant in tropical and South Africa and Madagascar. Two species, *A. monostachyon* Linn. and *A. crispum* Thunb., are common in the Gangetic Plain. The plants grow in ponds and on the border of Jhils, but *A. monostachyon* can also grow on moist land. As the life history of both these species is completely unknown, the present investigation was undertaken.

Previous Work

From the literature given by Schnarf (1931), it is seen that not much work has been done on the embryology of the genus *Aponogeton*. Out of the works mentioned there, those of Stenar (1925) and Suessenguth (1919) deal only with the development of pollen. Tischler (1915) and Clausen (1927) give an account of the periplasmodial development of the anther tapetum. Only Afzelius (1920) and Serguéeff (1907) have studied the development of the embryo-sac and endosperm, and the latter alone has studied the development of embryo. Afzelius has studied the development of the embryo-sac and endosperm in *A. ulvaceous*, *A. violaceous*, *A. Guillotii* and *A. quadrangularis*. Miss Serguéeff's thesis is a monographical study of *A. distachys* and deals with all phases of the life history of this species, though some parts of the account appear to be incorrect. No important work on the embryology of the family has appeared since the publication of Schnarf's book.

The results of the various investigations and the chief embryological features of the family known so far may be

summarized as follows:

Microsporogenesis. The cells of the tapetum form a periplasmodium. Division of the pollen mother cells is successive in *A. distachys* (Serguéeff, 1907) and *A. abyssinicus* (Stenar, 1925), but simultaneous in *A. distachys* according to Suessenguth (1919) and *A. ulvaceous* according to Stenar (1925). The mature pollen grains are 3-nucleate (Serguéeff, 1907).

Ovule. The nucellus is well developed. There are two free integuments in *A. ulvaceous*, *A. violaceous* and *A. Guillotii* (Afzelius, 1920), two partly fused ones in *A. quadrangularis* (Afzelius, 1920), and one in *A. distachys* (Serguéeff, 1907).

Embryo-sac. There is a single archesporial cell, which cuts off a primary wall cell. As an exception Afzelius (1920) found in *A. ulvaceous* a second archesporial cell situated below the normal one. The development of the embryo-sac follows the *Normal*-type. The polar nuclei fuse early and the secondary nucleus lies near the antipodal end of the embryo-sac.

Endosperm. The development of the endosperm follows the *Helobial*-type. Serguéeff (1907) described nuclear endosperm in *A. distachys*, but this appears to be an incorrect observation.

Embryo. The suspensor cell at the micropylar end grows into a large bladder-like cell and its nucleus becomes hypertrophied.

Material and Methods

Both *Aponogeton monostachyon* and *A. crispum* are quite common in the vicinity of the Benares Hindu University. They flower during the rainy season, the former species a little earlier than the latter. The flowering spikes are dense and purple in the first, but lax and white in the second.

The material of *A. monostachyon* was collected from the ponds in the Benares Hindu University area and that of *A. crispum* from a village about two miles from the university. It was fixed on sunny days and at various times from 9 A.M. to 2 P.M. Nawaschin's fluid and Formalin-Acetic-Alcohol were the fixatives used. Both gave satisfactory results. An exhaust pump was used, especially with Nawaschin's fixative, to facilitate the sinking of the material. Usual methods of dehydration and infiltration were followed. Sections were cut 5-12 μ thick depending on the age of the material and stage desired. Heidenhain's Iron-alum Haematoxylin was mainly used for staining and differentiation was carried out with a saturated aqueous solution of picric acid. For early stages in anther and embryo development Delafield's Haematoxylin proved to be more convenient.

The two species have been found to agree in most of their embryological characters. Therefore, a common account has been written.

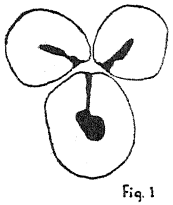


Fig. 1

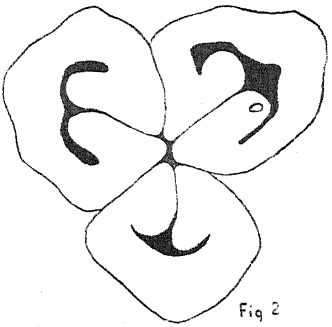


Fig 2

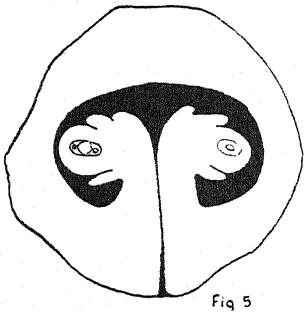


Fig 5

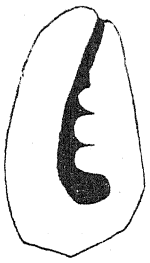


Fig 3

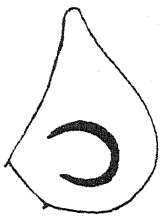


Fig 4

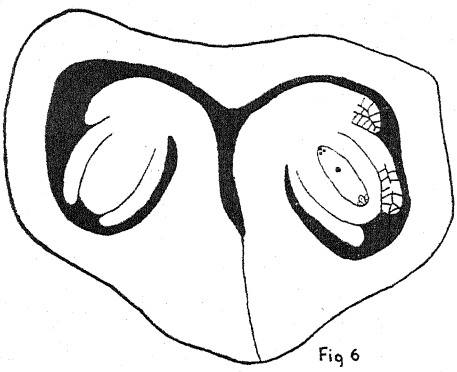


Fig 6

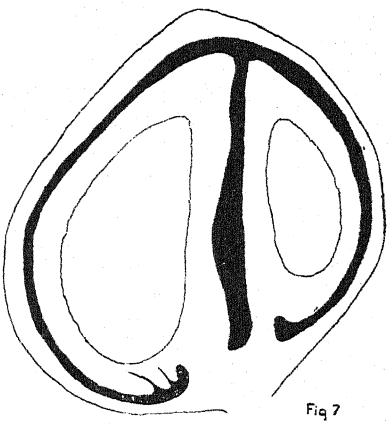


Fig 7

Figs. 1-7. *Aponogeton monostachyon.* Fig. 1, transverse section of a very young gynæcium showing three carpels with free margins. The ovule initials are yet very small. Fig. 2, transverse section of an older gynæcium showing three carpels with ovules at the archesporium stage. Fig. 3, longitudinal section of a carpel at the stage in Fig. 2 showing three ovules. ×110. Fig. 4. *A. crispum.* Longitudinal section of a carpel showing only one ovule. ×110. Figs. 5-6. *A. monostachyon.* Transverse sections of carpels showing ovules, in Fig. 5 at the 2-nucleate embryo-sac and 1-nucleate embryo-sac stages, in Fig. 6 at the mature embryo-sac stage. ×110. Fig. 7. *A. crispum.* Longitudinal section of a carpel during the development of the embryo. The ovules are orientated vertically and their micropyles point towards the base of the carpel. ×25.

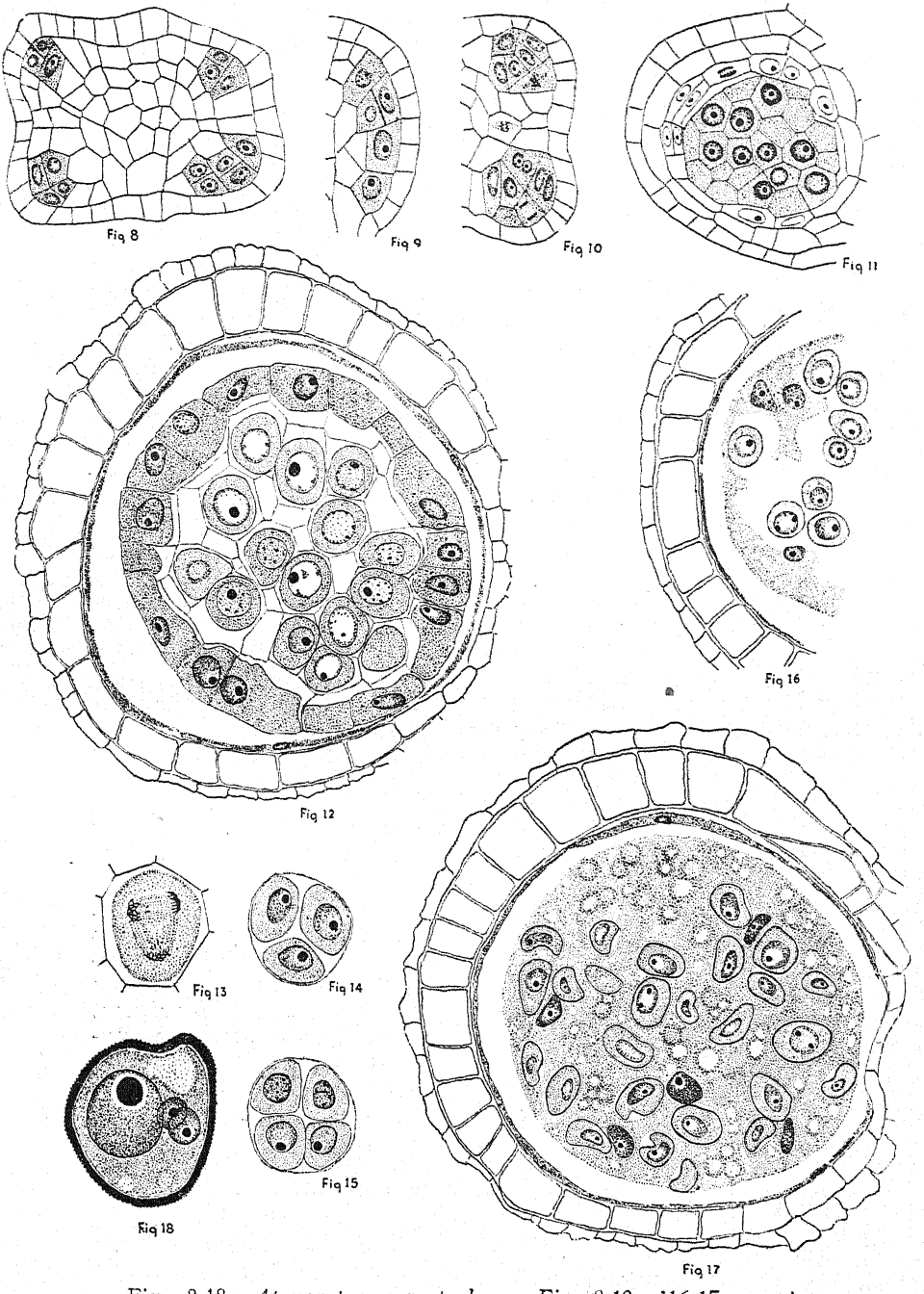
Microsporogenesis

The various floral parts develop in the usual acropetal order, the sequence being perianth, outer whorl of stamens, inner whorl of stamens and the carpels.

The primary archesporium in an anther-lobe consists of one to three hypodermal rows of archesporial cells, which are easily distinguished from other cells by their size, large nuclei and a slightly different staining capacity (Fig. 8). Longitudinal sections show that each row comprises three to four cells (Fig. 9). Periclinal divisions in the primary archesporial cells cut off towards the outside a layer of primary wall cells and simultaneously with this the anther begins to lobe. The primary wall cells divide and form two layers. Of these, the one next to the epidermis develops into the fibrous endothecium, while the inner one again forms two layers. The innermost one of these develops into the tapetum, while the one adjacent to the endothecial layer degenerates at an early stage of anther development (Figs. 10-12). Johri (1935 and 1936) has shown that the tapetum in Alismaceae and Butomaceae is also of parietal origin. This clearly shows that the claims of Rosenberg (1901), Holmgren (1913) and other older workers that the tapetum in the Helobiales has a sporogenous origin are no longer tenable.

About the time of tetrad formation the tapetal cells lose their walls and their protoplasts begin to project into the interior of the anther-lobes (Fig. 16). The irregular projections gradually penetrate in between the microspores forming a periplasmodium in which the microspores lie embedded (Fig. 17). The nuclei of the tapetal cells undergo no division during the division of the pollen mother cells and the tapetal cells remain uni-nucleate throughout their existence as in *Delphinium Ajacis* and *Phlox paniculata* investigated by Cooper (1933). On the formation of the periplasmodium the nuclei of the tapetal cells float freely as deeply staining structures in between the pollen grains. As the pollen grains mature, the periplasmodium is gradually used up and disappears. It appears to serve a nutritive function.

The pollen mother cells undergo the two meiotic divisions in the normal manner. No wall is formed at the end of the first meiotic division. At the end of the second meiotic division the pollen mother cells contain four nuclei arranged in a tetrahedral or rarely isobilateral fashion (Fig. 13). The formation of the pollen grains in both the species takes place according to the simultaneous type, as in *Aponogeton distachys* (Suessenguth, 1919) and *A. ulvaceous* (Stenar, 1925). The pollen tetrads are generally tetrahedral (Fig. 14), but rarely isobilateral (Fig. 15), depending upon the arrangement of the nuclei at the end of the second meiotic division. The mature pollen grains have a furrow on one side and are three-nucleate (Fig. 18). The exine is rough on the outside.



Figs. 8-18. *Aponogeton monostachyon*. Figs. 8-12and16-17, various stages in the development of the anther, Fig. 9 from a longitudinal section, the rest from transverse sections. Fig. 13, a pollen mother cell in the telophase of the second meiotic division. Figs. 14 and 15, two pollen tetrads. Fig. 18, a mature pollen grain. Figs. 8-12 and 16-17, ×440; Figs. 13-15 and 18, ×880.

The Gynaecium and the Ovule

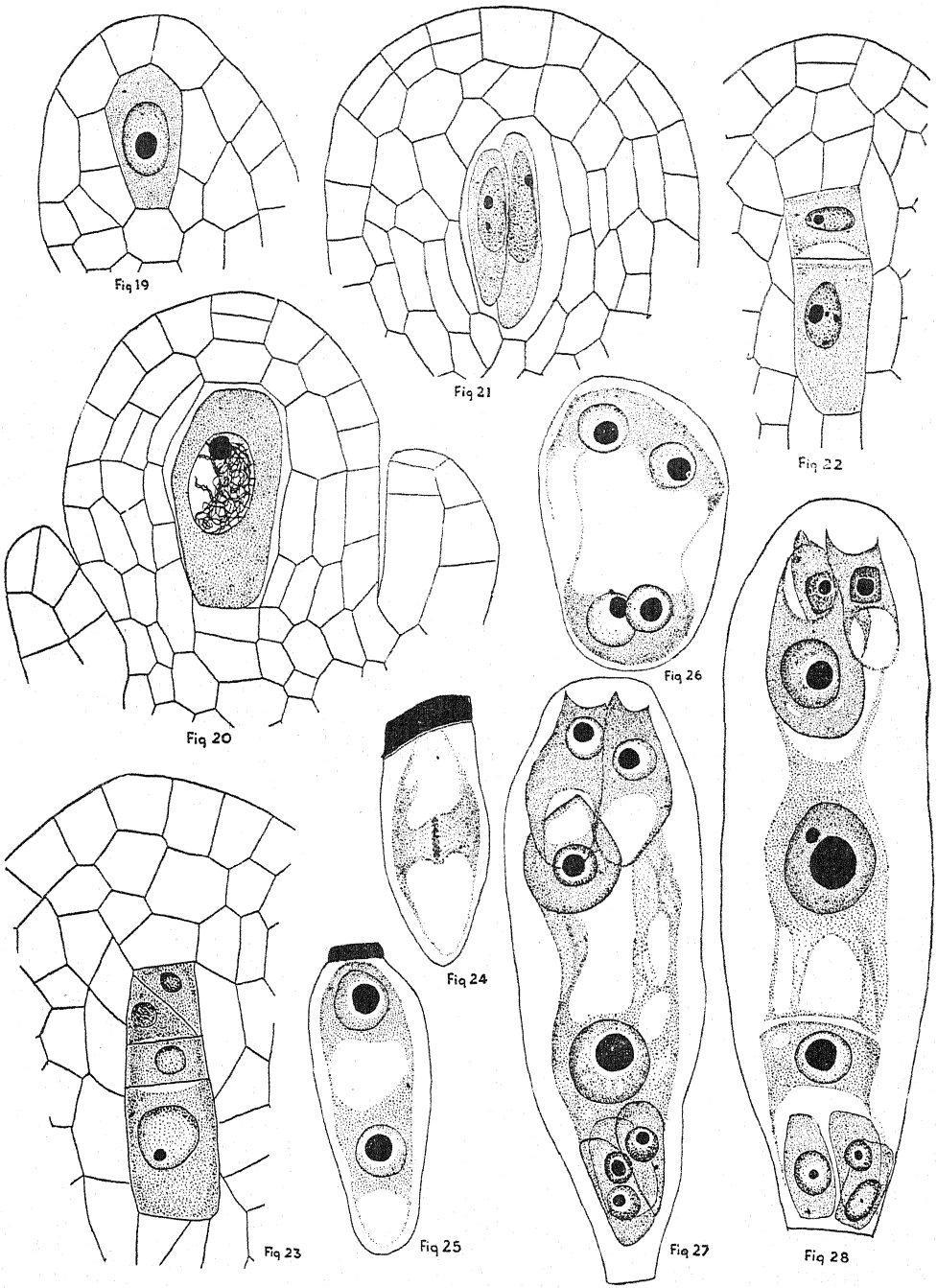
The gynaecium both in *Aponogeton monostachyon* and *A. crispum* consists of three free carpels. The margins of the individual carpels are quite free in the beginning (Figs. 1, 2 and 5) and fuse only at a very late stage of development, but even then quite often the line of fusion can be made out (Fig. 6). This, as Arber (1937) and Joshi (1935) have pointed out, supports the classical view about the nature of the angiospermous carpel.

The ovules arise as small protuberances from the margins of the carpels and various stages in their development are shown in Figs. 1-7. They grow straight at first till they meet the dorsal wall of the carpel (Fig. 2). Now they turn outwards (Fig. 5) and then again inwards (Fig. 6). In this manner the mature ovules assume an anatropous form. The number of ovules in a carpel in the two species is different. In *A. monostachyon* there are 4-8 ovules in each carpel (Fig. 3), but in *A. crispum* the carpels possess only two ovules (Figs. 4 and 7). In the mature condition the ovules in *A. monostachyon* lie at right angles to the long axis of the flower and retain this position even during the development of the embryo. The early stages of the development of the ovules in *A. crispum* are similar to those of *A. monostachyon* but at the embryo-sac stage their position is somewhat oblique and after fertilisation growth proceeds in such a way that the mature seeds lie vertically in each carpel (Fig. 7).

The integuments arise as cup-like outgrowths from the base of the nucellus. In *A. monostachyon*, the two integuments are free from one another and the nucellus (Fig. 6). The inner integument is two-layered except at the micropylar end, where it is thicker and may be three or four-layered. The outer integument is three-layered and incomplete on the side of the raphe. It does not take part in the formation of the micropyle. Only late after fertilisation it overgrows the inner integument. The micropyle is usually quite wide.

A. crispum in this respect has a quite different structure. In the young condition the two integuments appear as two separate structures, but during further growth only the concrescent basal part seems to grow, so that in the mature ovule the two integuments can be made out only in the micropylar region. In this respect *A. crispum* shows similarity with *A. quadrangularis* (Afzelius, 1920), while *A. monostachyon* agrees in the structure of the integuments with *A. ulvaceous*, *A. violaceous* and *A. Guillotii* (Afzelius, 1920). As in *A. monostachyon*, the outer integument in *A. crispum* is incomplete on the side of the raphe and does not take part in the formation of the micropyle. The two integuments together have a thickness of five to six layers of all ?

The nucellus is well developed in both the species and shows irregular periclinal divisions in the epidermis (Figs. 20-22).



Figs. 19—28. *Aponogeton monostachyon*. Various stages in the development of the embryo-sac and a stage in the development of endosperm. Fig. 19, primary archesporium. Fig. 20, megaspore mother cell. Fig. 21, two megaspore mother cells. Fig. 22, a dyad. Fig. 23, a tetrad. Fig. 24, division of the nucleus in the 1-nucleate embryo-sac. Fig. 25, 2-nucleate embryo-sac. Fig. 26, 4-nucleate embryo-sac. Fig. 27, mature embryo-sac. Fig. 28, an embryo-sac after fertilisation and first division of the endosperm

Development and Structure of the Embryo-sac

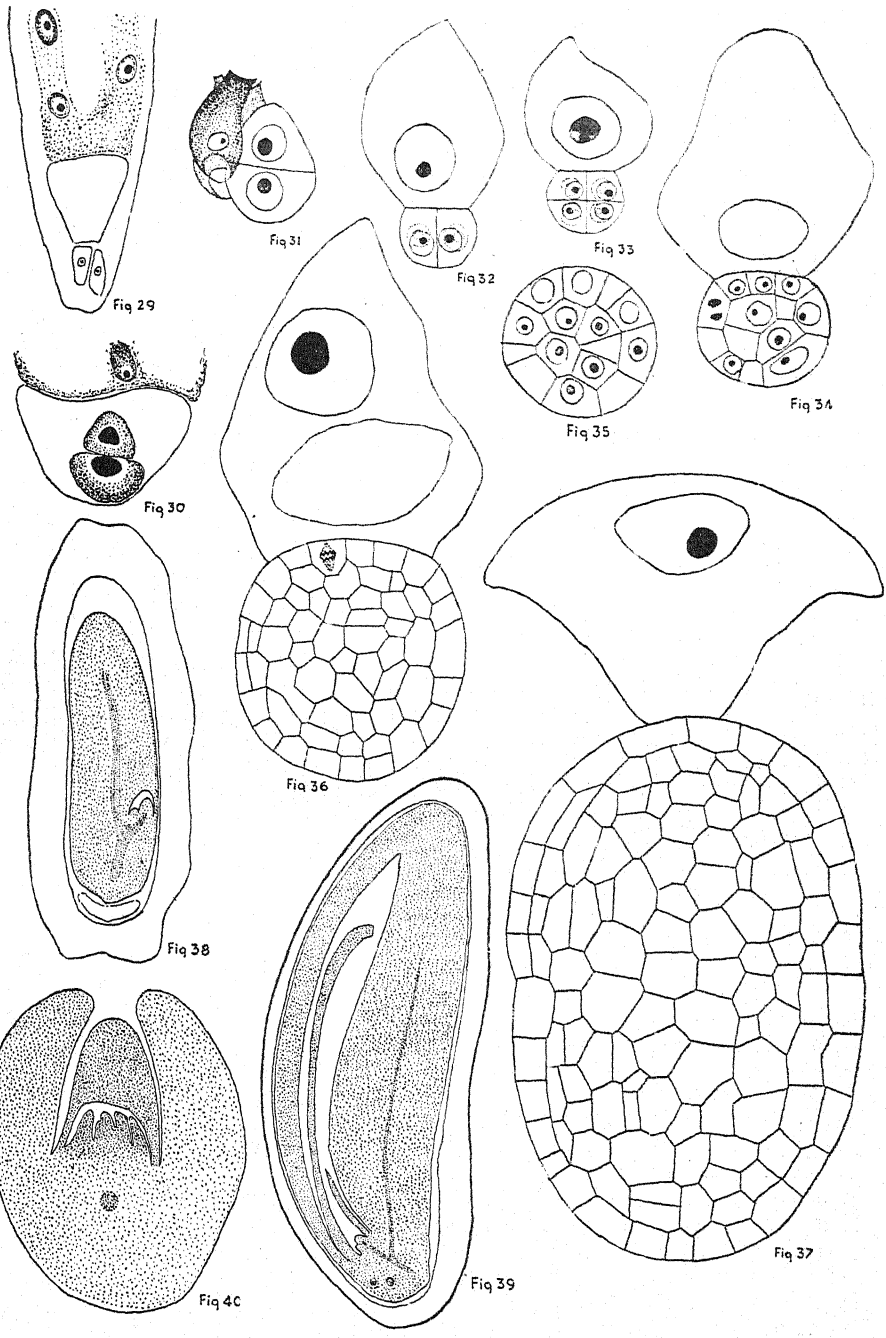
A single hypodermal cell of the young ovule enlarges and differentiates as the primary archesporial cell (Fig. 19). It cuts off a parietal cell and becomes the megaspore mother cell (Fig. 20). In one case in *Aponogeton monostachyon* two megaspore mother cells were found lying side by side (Fig. 21). The first division of the parietal cell may be periclinal or anticlinal and it gives rise to two layers of wall cells in *A. monostachyon* and to three layers in *A. crispum*. The first meiotic division in the megaspore mother cell leads to the formation of a normal dyad (Fig. 22). During the second meiotic division the spindle in the micropylar dyad cell is obliquely orientated. In this manner the megaspore mother cell gives rise to a linear tetrad, in which the wall separating the two micropylar megaspores is obliquely placed (Fig. 23). This type of tetrad appears to be quite common in the Helobiales (Schnarf, 1929). Afzelius (1920) did not see the micropylar dyad cell dividing in the species of *Aponogeton* that he investigated, while Serguéeff's (1907) description of the conditions in *A. distachys* is limited to 'a linear tetrad' and she gives no figures.

Further development of the embryo-sac takes place after the *Normal*-type. The three micropylar megaspores degenerate very rapidly, so that in most cases their traces are not to be found even at the uni-nucleate stage of the embryo-sac. The functional chalazal megaspore enlarges and develops two vacuoles, one at each end, with the nucleus lying in the centre. The nucleus now divides (Fig. 24). The spindle is orientated at right angles or obliquely to the long axis of the cell. The two daughter nuclei migrate to the poles and a large vacuole appears in the centre. In this manner a typical 2-nucleate embryo-sac is formed, but sometimes the chalazal vacuole is seen to persist even up to this stage (Fig. 25). The 4-nucleate stage of the embryo-sac is quite normal (Fig. 26). The four nuclei undergo one more division and a normal 8-nucleate embryo-sac is formed.

The mature embryo-sac in both the species has more or less the same appearance. It is broader at the micropylar end and narrowed towards the antipodal end (Figs. 27-28). The embryo-sac in the species studied by Afzelius (1920) has the same form. The egg is pear-shaped and possesses a vacuole at the micropylar end and a nucleus at the chalazal end. The synergids as usual show a large vacuole in the chalazal part and a nucleus in the micropylar half. The antipodals, which are situated in the narrow chalazal end of the embryo-sac, are generally without any vacuoles. The two polar nuclei fuse early and the secondary nucleus thus produced lies in the vicinity of the antipodals.

Fertilisation was not observed, but none of the synergids appears to be destroyed in the process, since both of them have been

except Fig. 35, which shows a transverse section of the embryo sketched in Fig. 34. Fig. 38, longitudinal section of the seed showing the mature embryo. Figs. 29-37, ×400; Fig. 38, ×45. Figs. 39-40. *Aponogeton crispum*. Fig. 39, longitudinal section of a seed showing the form of the embryo. Fig. 40, a transverse section of the embryo. Fig. 39, ×20; Fig. 40, ×45.



Figs. 29-38. *Aponogeton monostachyon*. Figs. 29 and 30, chalazal portions of two embryo-sacs showing the development of endosperm. In the embryo-sac sketched in Fig. 29 a 16-celled embryo was seen at the micropylar end. Antipodals are seen in Fig. 29 below the endosperm. In Fig. 30 the chalazal cell of the endosperm shows two nuclei. Figs. 31-37, various stages in the development of the embryo, all from longitudinal sections

observed intact even after the first division of the fertilised egg (Fig. 31). They are also seen in Fig. 28, which represents an embryo-sac after fertilisation and the first division of the primary endosperm nucleus. The antipodals are reported by Schnarf (1931) to degenerate early, but in the present case they have been found to persist after fertilisation (Fig. 28) and even up to the 16-celled stage of the embryo (Fig. 29). From the figures of Afzelius (1920) it is clear that they are present at least up to the 2-celled stage of the embryo in some of the species studied by him.

Endosperm

The endosperm development follows the *Helobial*—type (Figs. 28-30). The primary endosperm nucleus divides into two and a plasma membrane divides the embryo-sac into two parts, a small chalazal and a large micropylar part. The nucleus in the chalazal part generally does not divide further, but only increases in size. Only in one case in *A. monostachyon* it was found to have divided once (Fig. 30). The nucleus in the micropylar part by repeated divisions forms a thin layer of endosperm, which is ultimately completely absorbed by the developing embryo. Miss Sergueeff (1907) described nuclear endosperm in *A. distachys*, but as pointed out by Afzelius (1920), it seems probable that she overlooked the chalazal cell of the endosperm, since all the species of Helobiales investigated so far possess only the *Helobial*-type of endosperm.

Embryo

The first division of the oospore is by a transverse wall and gives rise to a basal and an apical cell (Fig. 31). The basal cell does not divide any further and directly forms the suspensor. It undergoes great increase in size, developing into a bladder-like structure, and its nucleus also becomes hypertrophied (Figs. 32-34, 36 and 37). The apical cell gives rise to the embryo proper. It divides by two longitudinal walls at right angles to each other and thus forms the quadrants (Fig. 32). This is followed by the transverse division of each of the four cells and the embryo reaches the octant stage (Fig. 33). Now these cells divide by periclinal walls and the dermatogen is differentiated (Figs. 34 and 35). The cells of the dermatogen after their differentiation generally divide only by anticlinal walls, but occasionally in *A. monostachyon* they have been seen to divide periclinally also (Fig. 36). The periblem and plerome differentiate at a very late stage. Further stages in the development of the embryo are shown by Figs. 36 and 37. The whole thing develops into a globular mass, from which the various organs are gradually differentiated, the radicle from the micropylar end, the single cotyledon from the other end and the plumule from somewhere near the middle. No definite relation could be made out between the quadrants and the various parts of the embryo.

The mature embryo has the form typical of the Helobiales (Figs. 38—40). That of *A. monostachyon* shows the rudiment of a foliage leaf besides the cotyledon (Fig. 38). The cotyledon is cylindrical and circular in cross section. The plumule lies in a notch at the base of the cotyledon on one side. The testa in this species shows faint longitudinal ridges on the outside. In *A. crispum*, the cotyledon is crescent-shaped in cross section and the embryo shows rudiments of 3—4 foliage leaves (Figs. 39 and 40). Besides the radicle, initials of a few adventitious roots are also present. The seeds are quite smooth. In both cases the endosperm and the nucellus are completely absorbed in the mature seed, and the cells of the embryo, particularly, the cotyledon, are richly laden with starch. The fruit in both cases consists of 1-3 follicles.

Summary

The embryology of *Aponogeton monostachyon* and *A. crispum* has been studied.

The primary archesporium in the anther consists of 1-3 rows of hypodermal cells in each lobe, each row comprising 3-4 cells. The tapetum is of parietal origin. The tapetal cells remain uninucleate throughout their life. A true periplasmodium is formed. The pollen grains are formed in the simultaneous manner. The mature pollen grains are 3-nucleate and one-furrowed.

The carpels of *A. monostachyon* are 4-8-ovuled, those of *A. crispum* only 2-ovuled. The ovules are anatropous, bitegmic and with well developed nucellus. The two integuments are free in *A. monostachyon*, but united for the most part in *A. crispum*. The micropyle is formed only by the inner integument.

The archesporium in the ovule is mostly limited to a single hypodermal cell, but occasionally two cells may be present in *A. monostachyon*. A primary wall cell is cut off. The megaspore mother cell gives rise to four megaspores. The chalazal one of these develops into an 8-nucleate embryo-sac according to the *Normal*-type. Antipodals persist for a long time. Synergids have been observed in the embryo-sac even after the first division of the oospore. The polar nuclei fuse early, the secondary nucleus taking up a position close to the antipodals.

The endosperm develops according to the *Helobial*-type. The proembryo is only 2-celled. The basal cell enlarges to form a bladder-like suspensor with a much hypertrophied nucleus. The mature embryo has the form characteristic of the Helobiales. In *A. monostachyon* it shows one, in *A. crispum* 3-4 foliage leaves besides the cotyledon. Both the endosperm and the nucellus are completely absorbed by the developing embryo.

Acknowledgements

The author takes great pleasure in acknowledging his indebtedness to Dr. A. C. Joshi for his guidance and encouragement during the investigation. He is also thankful to Dr. P.N. Roy of the Department of Modern European Languages for help in translating some of the literature in French.

Literature Cited

1. Afzelius, K.—1920. Einige Beobachtungen über die Samenentwicklung der Aponogetonaceæ. *Svensk Bot. Tidsk.*, 14: 168—175.

2. Arber, A.—1937. The interpretation of the flower: A study of some aspects of morphological thought. *Biol. Rev.*, 12: 157—184.

3. Clausen, P.—1927. Über das Verhalten des Antherentapetums bei einigen Monocotylen und Ranales. *Bot. Arch. Mez.*, 18: 1—27.

4. Cooper, D. C.—1933. Nuclear divisions in the tapetal cells of certain angiosperms. *Amer. Jour. Bot.*, 20: 358—364.

5. Holmgren, I.—1913. Zur Entwicklungsgeschichte von *Butomus umbellatus*. *Svensk Bot. Tidsk.*, 7: 58—77.

6. Johri, B. M.—1935. Studies in the family Alismaceae. I. *Limnophyton obtusifolium* Miq. *Jour. Ind. Bot. Soc.*, 14: 49—66.

7. ————. 1936. Life history of *Butomopsis lanceolata* Kunth. *Proc. Ind. Acad. Sci.*, B, 4: 139—162.

8. Joshi, A. C.—Criticism of Dr. Thomas's recent hypothesis on the nature of the angiospermous carpel. *Jour. Bot.*, 73: 286—294.

9. Rosenberg, O.—1901. Über die Embryologie von *Zostera marina* L. *Bihang Svenska Vetensk-Akad. Handl.*, 27, Afd. III, No. 6.

10. Schnarf, K.—1929. Embryologie der Angiospermen. *Berlin.*

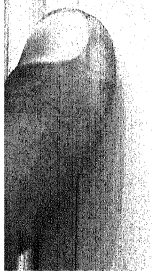
11. ————1931. Vergleichende Embryologie der Angiospermen. *Berlin.*

12. Sergueeff, M.—1907, Contribution à la morphologie et la biologie des Aponogetonacées. *Thèse Genève.*

13. STENAR, H.—1925. Embryologische Studien. I. Zur Embryologie einiger Columniferen. II. Die Embryologie der Amaryllidaceen. *Akad. Abh., Uppsala.*

14. SUESSENGUTH, K.—1919. Beiträge zur Frage des systematischen Anschlusses der Monocotylen. *Diss. München.*

15. TISCHLER, G.—1915. Die Periplasmodienbildung in den Antheren der Commelinaceen und Ausblicke auf das Verhalten der Tapetenzellen bei den übrigen Monocotylen. *Jahrb. f. wiss.* Bot., 55: 52—90.



REVIEWS

SMITH, G. M. *Cryptogamic Botany, Vol. I. Algæ and Fungi* McGraw-Hill Publishing Co., Ltd., London 1938: 24 s. pp. 545. 299 figs. *Cryptogamic Botany, Vol. II. Bryophytes and Pteridophytes.* McGraw-Hill Publishing Co., Ltd., London 1938: 18 s. pp. 380. 224 figs.

Teachers and students of Botany have reasons to feel gratified at the appearance of these two volumes. Out of a total of 925 pages, 350 are devoted to Algæ, 173 to Fungi, 113 to Bryophytes, 252 to Pteridophytes and the rest to the index. The method of treatment is by types, but the information has been so skilfully presented that students who have gone through the book will find no difficulty in understanding the more advanced texts written for the specialist.

The part on algæ is the most exhaustive and perhaps also the best written. From the standpoint of the English-reading student this is the finest general presentation of the group, for the other texts so far published on this subject deal almost exclusively with the green algæ. The fungi have, in our opinion, been slightly let down. Although the life-histories are clearly presented, the growing importance of plant pathology and mycology demanded a greater attention to this group than has been given to it by the author. We recognise, however, that in covering so vast a field with a single pen, it is inevitable that some parts should be better done than others. The bryophytes and pteridophytes receive a fair space and the account is simple and straightforward. After Campbell's "Mosses and Ferns", which is now entirely out of date, this is the first volume that deals with the Archegoniatæ in a way that is suitable for the student.

At the end of every chapter there is a selected bibliography, which will be of immense value to the teacher and the ambitious student.

The illustrations are excellent. The author was fortunate in having the services of an experienced technician like Dr. Donald A. Johansen for preparing the slides from which some of the figures have been drawn.

The text adequately fulfils the objectives the author had in view. Indeed, we regard it as one of the most arresting publications that have appeared on Plant Morphology. The reviewer has added much to his knowledge of Botany by going through it. It is however felt that it should more appropriately be called a "Morphology of Cryptogams" rather than "Cryptogamic Botany".

P. MAHESHWARI.

AN INTRODUCTION TO BOTANY with special reference to the structure of the flowering plant: By J. H. PRIESTLEY, Professor of Botany, University of Leeds, and Lorna I. Scott, Lecturer in Botany, University of Leeds: pp. 148, price 17s. 6d.: Longmans, Green & Co. Ltd., London, New York, Toronto.

An introduction to Botany from a distinguished author like Professor Priestly is welcome. A perusal of the book fully justifies expectations. The book, as the title-page states, has special reference to the structure of the flowering plant, but that does not mean that it is incomplete.

The subject has been treated in an original and interesting manner that holds the attention of the reader throughout. All the 39 chapters of the book are so interesting that it is difficult to pick out any one for individual reference, but one must make special mention of chapters VII—XII, dealing with growth forms and of chapters XXII—XXVI, dealing with the structure of dicotyledons and monocotyledons, as the most interesting.

Among the chapters dealing with elementary plant physiology, a chapter on the Carbon Atom is a welcome feature.

The printing and illustrations are good. Naturally all the examples and materials are from the British flora, but the methods are so universal that an Indian teacher will find no difficulty in selecting his material from among the local plants.

This book will not only be useful to teachers and students of elementary botany, but even the advanced students will profit by its perusal. This book should find a place in all public and private libraries.

P. PARIJA.

The Journal of the Indian Botanical Society

(Formerly "The Journal of Indian Botany")

VOL. XVIII NOVEMBER, 1939 No. 3

THE SPECIES OF GERANIACEAE OCCURRING ON THE TRAVANCORE HIGH RANGE INCLUDING THE DESCRIPTION OF A NEW BALSAM

BY

EDWARD BARNES

Received for publication on 17th July, 1939

The Travancore High Range is the highest range of hills in South India, three of its peaks being higher than Dodabetta of the Nilgiris. Owing to its proximity to the West Coast, a large part of this range receives a very heavy rainfall during the period of the S. W. monsoon. These two facts contribute to make this one of the botanically richest areas of India south of the Himalayas. During the wetter months of the year, a striking feature of the vegetation of these hills is the great profusion of balsams. In his "Praecursores ad Floram Indicam–Balsamineae" Sir J. D. Hooker states that the genus *Impatiens* attains its maximum development in India, and that the Western Ghats is the most prolific area in species. There seems little doubt that in respect of species of balsams the High Range is the richest area of the Western Ghats, and consequently of the world. Of the balsams listed below more than thirty species are found within a radius of 10 miles of Munnar, and most of these within a much smaller area.

In the same monograph and in the more recent "Epitome of the British Indian Species of Impatiens", Hooker points out that in the Western Ghats a much greater proportion of the species is endemic than is the case in any other area, that the species in the Sections *Scapigerae* and *Epiphyticae* are entirely

confined to South India (except one of the former found also in Ceylon), and that no species with the long narrow capsule characteristic of the Himalayan and Burmese forms occurs in the Peninsula. Very similar statements may be made with regard to the distribution of balsams in the various parts of the Western Ghats. Here the Palghat Gap acts as the chief dividing factor. Of the 83 species of balsams so far found in the area covered by the Flora of Madras, 36 occur only south of the Palghat Gap, and 23 occur only north of the Gap. Of the 28 caulescent pedunculate species, that is those belonging to Hooker's Sections *Epiphyticae*, *Subumbellatae* and *Racemosae*, all occur on the hills south of the Gap, but only two species, *I. Goughii* and *I. fruticosa*, are common on the Nilgiris and other hills to the north. On the other hand, of the fifteen species of *Scapigerae* found in the Flora of Madras area, ten are found only north of the Palghat Gap and only two nearly allied species are confined to the south. Twelve species of balsams appear to be endemic to the High Range. These facts are largely accounted for by the feeble method of dispersal found in this genus (explosive capsules), and by the exacting requirements of most species in regard to moisture and temperature. From their present distribution it appears probable that the scapigerous balsams originated on the Western Ghats north of the Palghat Gap, and the caulescent pedunculate species to the south. It is interesting to note that most of the species occurring outside the suggested area of origin of their group have very small hygroscopically hairy seeds. This is the case with *I. parasitica* and *I. Goughii* found north of the Gap, and *I. scapiflora*, *I. modesta* and *I. acaulis* found south of the Gap, the last extending as far as Ceylon. When these seeds fall on a wet surface the hairs expand; when the surface dries the hairs adhere to it and so anchor the seed. The primary function of this adaptation is no doubt to prevent the seeds from being carried beyond the habitat of the plant by heavy rain or running water, but it also makes possible their dispersal to distant places. Several species of wagtails frequent the streams and wet rocks of the Western Ghats where these balsams grow, and these birds are known to have an annual north and south migration. It appears likely that they may occasionally carry the seeds of these balsams attached to their feet from one area to another. It also appears likely that birds are responsible for transferring the seeds of the balsams of the *Epiphyticae* group from tree to tree and from shola to shola.

Most of the species recorded below are quite distinctive and offer little difficulty in determination, but this is not the case with a number belonging to Hooker's *Annuae* (Nos. 7, 10, 12, 13 and 14). These plants are very variable according to the conditions of growth, and it is often difficult to decide to which species a variant should be assigned. The difficulty is probably complicated by crossing occurring between certain of these nearly related species.

The few species of the other genera of Bentham and Hooker's *Geraniaceae* found on these hills are included in the list. The areas in brackets indicate the previously recorded distribution of the species. In addition to recently described species, seventeen others in the list are not recorded in the Flora of Madras as occurring on the Travancore hills. Two species of *Impatiens*, *I. macrocarpa*, Hk. f. and *I. verecunda*, Hk. f. were discovered on the High Range by Meebold about 1909, but have not been found by the writer. The total number of balsams known to occur in this area is thus 39, and it is highly probable that other new species of very restricted distribution remain to be discovered. Nine other species not in the list have been reported from the Travancore Hills without exact locality and may have been collected in the High Range.

All the plants in the list were collected during a series of visits to the area during the years 1931-37. The numbers refer to the sheets in the writer's herbarium. Some notes on seeds have been added as these are frequently lacking in the original descriptions.

The writer wishes to thank Mr. C. E. C. Fischer of the Kew Herbarium for his help with a number of doubtful cases, and Mr. A. Abraham, M. A., for the diagrams.

GERANIUM

1. *G. nepalense*, Sweet.

   Frequent in grassland above 6,000 ft. Anaimudi slopes, Chunduvurrai, Koilur–Pambadi Shola. 1794. Fl. May. (Nilgiri and Pulney Hills)

OXALIS

1. *O. corniculata*, Linn.

   Very common throughout the area especially as a weed in tea plantations.

BIOPHYTUM

1. *B. Candolleanum*, Wt.

   Frequent throughout the area in shady places at about 5,000 ft. Munnar, Kandalur, near Lockhart Gap. 142, 143, 1719, 1737, 2027, Fl. September. (W. Ghats in Nilgiris)

2. *B. Reinwardtii*, Edg.

   Slopes below Lockhart Gap. 1663. Fl. September. (W. Coast, W. Ghats, Anamalai Hills)

3. *B. intermedium*, Wt.

   Along the margins of tree-shaded streams. Karankulam c. 7,000 ft. Fl. September. Near Perumalai on the lower margins of Mannavan Shola c. 5,000 ft. Fl. December. 1639-41, 1716, 1850.

The variety *pulneyense*, Edg. and Hook. f. is well known from the Pulneys, but the typical form was known only from Ceylon till found by the writer in Tinnevelly (Kew Bull. 1938, p. 32). It has now been found on the High Range. The stems of this plant repeatedly bifurcate at the whorls of leaves and become procumbent. The stems root at the old nodes from which the leaves have fallen, and a single plant may cover a number of square yards with a more or less dense growth. In var. *pulneyense* the plant is more or less erect as it divides into two or more branches a little above the root, but does not again branch.

IMPATIENS

1. *I. scapiflora*, Heyne

This is a widespread and variable species, several forms of which have been regarded as separate species or varieties by different botanists. Two forms are frequent on the High Range. On rocks exposed to the S. W. monsoon at elevations of about 5,000 ft. and upwards there occurs a form with thick reniform leaves having radiating nerves, and with a thick spur slightly dilated at the tip. (Spur 3–3.5 cms. long and 3-4 mm. across for most of its length) Lockhart Gap–Periakanal, 1314, 1315. Fl. September. At low elevations, usually on dripping rocks or in the splash of waterfalls, a taller form with ovate leaves having pinnate nerves, and with a slender tapering spur is found. This plant is very common and occurs at lower elevations than any other of the scapigerous balsams; on the Munnar-Neriamangalam Ghat Road it is found below 2,000 ft. 403-406, 409. Fl. September, December. (W. Ghats 6-8,000 ft.) A capsule contained 300 seeds. Seeds narrowly almond-shaped, 5 mm. long, reddish-brown, covered with white curled hairs.

2. *I. modesta*. Wt.

In shady places, often on tree-trunks. Periakanal, Tenmalai, near Munnar, Anaimudi (at 8,600 ft.), Kadalaar Valley 484, 485, 1322, 1563. Fl. September. (Nilgiri, Anamalai and Sivagiri Hills) Capsules contain about 30 seeds. Seeds 1 mm. long, ovoid, light brown, with longitudinal rows of minute pits and long coiled hairs.

3. *I. pandala*, Barnes (Kew Bull. 1938, p. 33)

On wet rocks in tufts of moss, and on cliffs, at high elevations. Anaimudi (7,000 ft. and above), Karankulam (7,000 ft.). 534, 536, 1642, 1643, Fl. September. Type in Kew Herb.

4. *I. parasitica*, Bedd.

Very common on branches of trees 4,000–7,000 ft., and in evergreen forest on rocks and banks. Kadalaar Valley, Munnar, Naimakad Gap, Karankulam, Periakanal. 510-513, 1532, 1681. Fl. September and October.

This plant is perennial. Moisture is stored in the stems, each internode of which, in the early stages of growth, is swollen to form a spherical warty-looking body. During the dry months of the year, owing to loss of moisture, the stems become flaccid and hang down from the branches of the trees. Soon after the beginning of the S. W. monsoon rains they again become erect. Seeds 50-60 per capsule, kidney-shaped, 1 mm. long, chocolate-brown, with long scattered white hairs.

5. *I. coelotropis*, C. E. C. Fisch. (Kew Bull. 1934, p. 390)

In sholas and evergreen forest. Naimakad Gap, slopes of Anaimudi at 6,500–7,500 ft. Fl. May and September. Kanniamalai, Kadalaar Valley. Fl. May. 602, 603. Type in Kew Herb.

6. *I. chinensis*, Linn.

The characteristic form of this species was found only in marshy places near Koilur and below Kandalur. 1861, 1862, 1729. Fl. December.

I. chinensis Linn. var. *brevicornis*, Barnes, var. nov. A formis typicis floribus minoribus, calcare quam alis breviore valde curvato differt.

A slender erect marsh herb, glabrous or shortly hairy, Leaves narrowly elliptic, oblong-lanceolate or linear-oblong, undersurface pale. Flowers up to about 1·8 cm. across; stipe of distal lobe of wing-petal slender; basal lobe very small, narrow and curved; lip boat-shaped with a much curved spur shorter than the wing petals, often coiled into a complete circle and sometimes shorter than the lip. Plants from higher elevations have shorter and broader leaves which are often scabrid, and shorter spurs.

Common in marshes and moist grasslands at Munnar and throughout the hills at about 5,000 ft., Fl. September, October. 553, 554, 556-558, 606, 1729, 1808.

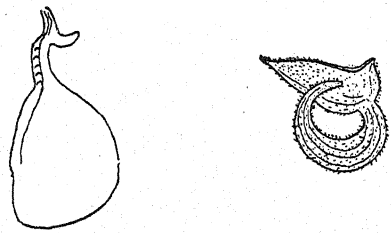


Fig. 1. *Impatiens chinensis* L. var. *brevicornis* Barnes; *a*, wing, *b*, lip. ×1·6.

7. *I. rivulicola,* Hook. f. ("forma" C. E. C. Fischer)

In and near Munnar along streams. Lockhart Gap–Periakanal, on rock slopes. 1661, 1692, 546, 566, 567, 1278, 1279. Fl. September. In this form the spur is reduced to a blunt cone.

8. *I. Aliciae,* C. E. C. Fischer (Kew Bull. 1934, p. 389)

Along streams Munnar-Neriamangalam Ghat Road. 1-5,000 ft., Fl. September. Type in Kew Herb.

9. *I. Kleinii,* W. & A.

Near Munnar. 572, 577. Fl. September. This species and *I. Rheedii,* W. & A. are very similar. They have similar flowers and both have a pair of roundish glands at the base of the leaf blade by which they are readily distinguished from other species. They differ from one another only in size of leaf and capsule, and an examination of numerous specimens makes it doubtful whether they should be regarded as specifically distinct.

10. *I. tenella,* Heyne

On the margins of streams near Munnar. Fl. September. 565, 569. (Nilgiris) The leaves are narrower and the flowers smaller than in typical Nilgiri plants, possibly var. *brachycarpa.* Some specimens (568, 1284) approach *I. debilis,* Turcz. but there is no specimen of the latter in Kew Herbarium for comparison and it is difficult to decide to which species they should be attached.

11. *I. munnarensis,* Barnes (Kew Bull. 1938, p. 32)

In streams and marshy places. Near Munnar, Kanniamalai 571, 573-5, 1275-7, 1652-3. Type in Kew Herb. Fl. September.

12. *I. herbicola,* Hook. f.

Common amongst grass. Munnar, Periakanal–Lockhart Gap, Chunduvurrai. Fl. September, October. 529, 532, 570, 1283. Four capsules contained 6, 6, 7 and 7 seeds.

13. *I. pallidiflora,* Hook. f. (" vel proxissima " Fischer)

On rock slopes above Periakanal. Fl. September. In a marsh at Santapara. Fl. May. 1535, 1632, 1686, 1756.

14. *I. tomentosa,* Heyne

Common amongst grass from 5,000 ft. upwards. Anaimud. at 8,800 ft., near Munnar, Kanniamalai, Kandale Valley, Chunduvurrai. 437, 481, 1788, 1793. Fl. May, September. Plants in unfavourable situations may have almost orbicular leaves only about ·25 in. long.

15. *I. rufescens*, Benth.

In marshy places. Anaimudi, near Devicolam, Palaar. 482, 1516, 1657. Fl. May, September. (Nilgiris) *I. rufescens* and *I. tomentosa* were united by Hooker but have again been separated. They differ in that the former, as found in the Nilgiris, is completely spurless while the latter, as found in the Pulneys, has a small hooked spur. Most of the specimens from the High Range classified as *I. rufescens* show a minute vestigial spur suggesting that this plant and *I. tomentosa* cannot be strictly separated. The form found near Devicolam has small bright yellow wing-petals.

16. *I. Gardneriana*, Wt.

Along streams. Munnar-Neriamangalam Ghat Road 2–3,000 ft. 594-6. Fl. September. (Nilgiris and Wynaad) Under favourable conditions this plant grows to about 4 ft. high and the lowest nodes become about an inch across. The capsules contain 8 or 9 seeds. Seeds ovoid, flattened, about 3 mm. long, covered with more or less appressed brown hairs, with a white membranous cap at one end (caruncle).

17. *I. Leschenaultii*, Wall.

On the margins of sholas. Naimakad Gap, slopes of Anaimudi at over 8,000 ft., Karankulam. 473, 474, Fl. September, December. (Nilgiri and Pulney Hills) Capsules contain 3–5 seeds. Seeds almond-shaped, 3 mm. long, dark purplish-brown, smooth.

18. *I. cuspidata*, Wt. (Ic. 741)

In sholas. Near Munnar, Naimakad Gap, Arivikad, Mannavan Shola 470—2, 1302, 1682, 1829, 1930. Fl. September, December. (Nilgiris) Plants from the High Range agree very closely with those from the Nilgiris except that the stem is not or only slightly glaucous. A shrub with pale pink or white flowers. Three capsules contained 7, 8 and 11 seeds.

19. *I. lucida*, Heyne.

On the margins of sholas and in cardamom plantations at about 4,000 ft. Near Munnar, Munnar-Neriamangalam Ghat Road, Periakanal. Fl. September. Cardamom Hills, Palaar. Fl. May. 593, 655, 1606, 1778, 1888.

20. *I. Balsamina*, Linn. var. *longiflora*, W. & A.

In moist places in drier areas. Marayur, Periakanal, Kandalur, Vatuvadai. 464-5, 1750. Fl. September.

21. *I. Hensloviana*, Arn.

Along streams in sholas, usually on slopes. Naimakad Gap, Periakanal, Karankulam, Kadalaar Valley. 448. Fl. May, September. (Nilgiri, Pulney and Tinnevelly Hills) Seeds

almond-shaped, 3 mm. long, rusty brown, surface rough and furrowed.

22. *I. Johnii*, E. Barnes sp. nov.

I. Hensloviana affinis, sed planta minor, floribus roseis, alarum lobis longis angustatis, vexillo cymbiformi differt. An erect shrubby plant up to about 1 metre high, branching from the base. Stem smooth, green, with blackish blotches at places, irregular, dilated at the nodes. Leaves opposite, whorled and alternate, ovate, acute at base, acuminate at apex, up to 13·5 x 5 cms., margin shallowly crenate-serrate, upper surface with scattered stiff white hairs, under surface paler, with stiff hairs on midrib and nerves only; nerves numerous, curved; petioles slender, up to 8 cms. long, channelled and roughly hairy along the upper side, red near blade. Pedicels solitary in upper leaf axils, without peduncle, slender, up to about 6.5 cms. long, with stiff scattered hairs, often red. Bracts about ·3 cm. long, lanceolate, with rough hairs on margin. Flowers over 4 cms. long. Lateral sepals braadly ovate, long acuminate, 1·3 cms. long, with stiff scattered hairs on margin and outer surface. Lip very shallowly boat-shaped, mucronate, with scattered hairs on under surface; spur up to about 4 cms. long, horizontal and moderately wide for a few mm. and then turning down and becoming slender and curved, roughly hairy, crimson at lower end. Wing petals bilobed to near base; deep pink becoming purplish near the base; dista lobe narrowly ovate, deeply notched at the apex, 3·5 x 1 cm.; basal lobe a little smaller, stepped near the apex on the inner margin. Standard boat-shaped, keeled along the back, truncate in front, glabrous, pink. Capsule light green, with a few stiff scattered hairs, 2·8 cms. long, acuminate at apex, with about 5 mature seeds. Seeds pear-shaped, somewhat flattened, about 4mm. long, surface covered with crusty tubercles, light brown.

Travancore High Range, Kalaar Valley, at 4,750 ft. in a stream bed in dense evergreen forest. 1646-1651, 1749. Fl. June-September. Seeds September. Named after Captain H. C. John of Periakanal at whose suggestion the writer visited the above area, and whose generous hospitality made a number of the collecting excursions possible. See Fig. 2.

23. *I. grandis*, Heyne.

In densely forested ravines at about 4,000 ft., not frequent. Kadalaar Valley. 1654. Fl. September. (Hills of S. Travancore and Tinnevelly)

24. *I. campanulata*, Wt.

Common in moist sholas at 5–6,000 ft. Naimakad, Lockhart Gap, Arivikad, Anaimudi, Pambadi Shola, Mannavan Shola,

Kadalaar Valley, Kanniamalai slopes. 528, 2099. Fl. May, September. Seeds 12-25 per capsule.

25. *I. verticillata,* Wt.

In running water at 3–4,000 ft. Marayur. Fl. September, Santapara. Fl. May. 538, 1562. Four capsules contained 14, 19, 19 and 25 seeds. Seeds almond-shaped, 2–2·5 mm. long, brown, with a tuft of white wooly hairs at the pointed end and long scattered hairs elsewhere.

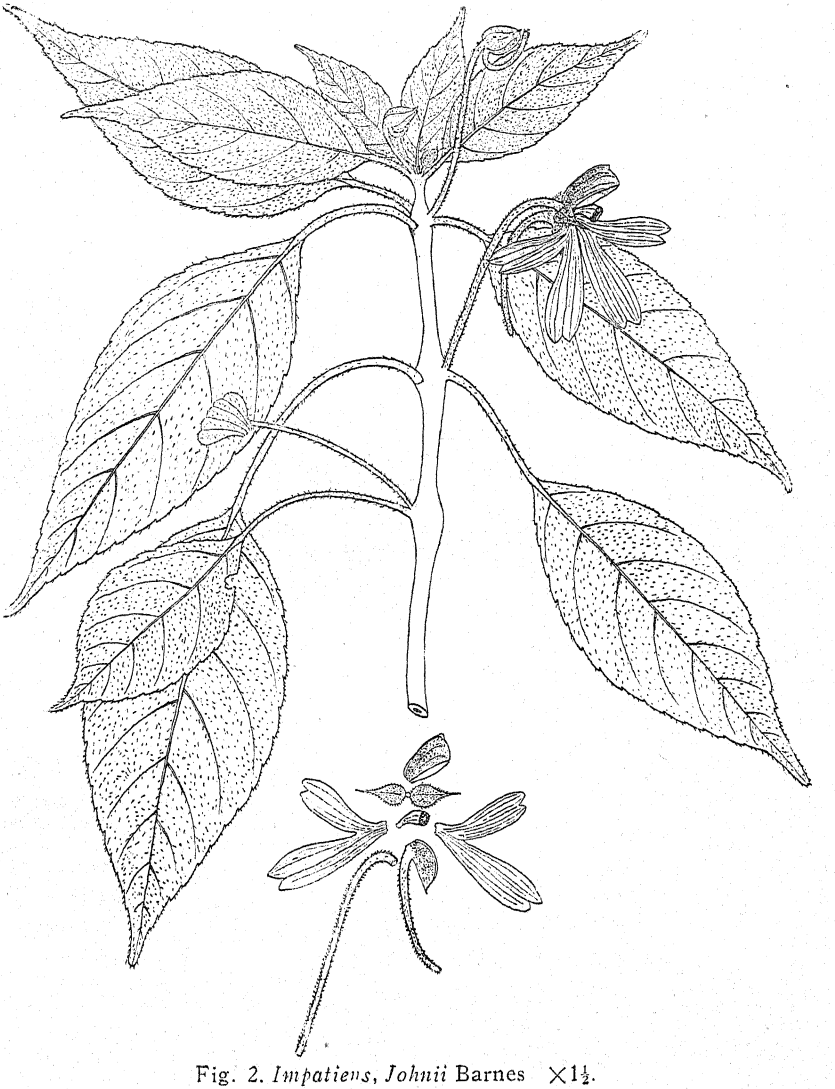


Fig. 2. *Impatiens, Johnii* Barnes ×1½.

26. *I. Goughii*, Wt.

Very common on wet rocks at 4–6,000 ft. Munnar, Devicolam, Naimakad Gap, Lockhart Gap, Periakanal, Palaar, Pullivasal. 492-503, 1303-4, 1655-6, 1662, 1679-80. Fl. May, September, December. According to conditions of growth this plant shows great variation in size and relative proportion of parts. Impoverished plants may be only 1–2 ins. high with leaves 0·25 ins. long; under specially favourable conditions they may be 2 ft. high and have leaves, including petiole, 6 ins. long. Some plants have many and large leaves and few flowers, and others few small leaves and numerous flowers. Occasionally the leaves are alternate. Some plants have deeply serrated leaves. A capsule contained 12 seeds. Seeds almond-shaped 1–5mm. long, chocolate, surface granular, with many short stout hairs.

27. *I. viscosa*, Bedd. (*I. Ballardi*, Bedd.)

Along streams. Munnar–Neriamangalam Ghat Road 2–3,000 ft. 664, 665, 1280, 1354. Fl. September, December.

28. *I. omissa*, Hook. f.

This balsam is included in the key in Hooker's Epitome of the British Indian Species of Impatiens, but no description has been published. The following description is from notes taken on the living plant.

A small erect herb up to 20 cms. high, sparingly branched. Stems slender, more or less square and channelled, red, roughly hairy just above the lower nodes, upper parts glabrous, nodes much swollen when branching. Leaves opposite, ovate, deeply serrate, up to 1·5 cms. long, pale and glabrous below, darker green above with a few scattered hairs; petioles up to 0·5 cm. Peduncles axillary, slender, up to 5 cms. long, sticky, few-flowered. Lateral sepals small, white-streaked-crimson, rounded tips dark red. Lip spoon-shaped, tip red; spur short, conical, streaked red. Wings up to 1·6 cms. long; distal lobe large, white marked pale crimson near base; basal lobe small, within the standard, streaked dark crimson; dorsal auricle short, acute, concave, bright orange. Standard obtusely ridged, with a small mucro behind the retuse tip. Seeds 2 mm. long, broadly ovate, flattened, dark brown, surface granular and with numerous stout white hairs. The flowers are sweet-scented. On wet rocks at about 7,000 ft. On the slopes of Anaimudi, Karankulam. 493-4. Fl. Sept. Grows in association with *I. pandata* (Anamalais and Palni Hills).

29. *I. cordata*, Wt.

Along almost every stream at 4–6,000 ft. sometimes on trees. Munnar, Pambadi Shola, Devicolam, Kalaar Valley,

Karankulam, Kandalur. 514-523, 1828. Fl. May, September, December. The common form has pink flowers. A form with white flowers marked crimson near the centre occurs near Pambadi Shola. Three capsules contained 11, 12 and 18 seeds. Seeds almond-shaped, 2·5 mm. long, brown, with a tuft of white hairs at the pointed end and scattered white hairs round the margin.

30. *I. leptura*, Hook. f. (Kew Bull. 1934, p. 391).

In evergreen forest at 4,000 ft. Kalaar and Kadalaar Valleys. 1607, 1644-5, 2100. Fl. May, September. (Anamalais) An erect unbranched suffruticose plant about 2 ft. high with very pale pink flowers. Seeds ovoid, flattened, 3–3·5 mm. long, light brown, surface slightly wrinkled, not hairy.

31. *I. travancorica*, Bedd.

On moss-covered rocks in evergreen forest. Kalaar and Kadalaar Valleys. 1514, 1521-2, 1678. Fl. May, September. (Myhendra and Aghasteer)

32. *I. anaimudica*, C. E. C. Fisch. (Kew Bull. 1935, p. 92)

In dense undergrowth in sholas. Anaimudi slopes at 8,000 ft. Fl. September, December. 579-81. Type in Kew Herb. Two capsules contained 55 and 67 seeds.

33. *I. maculata*, Wt.

Very common in streams and marshes at 4-5,000 ft. Munnar, Devikolam, Periakanal, Pallar, near Kandalur. 375-9. Fl. October, December. (Anamalais and Sivaghiris) Seven capsules averaged 22 seeds. Seeds almond-shaped, 2 mm. long, chocolate-brown, with brown appressed hairs.

34. *I. phoenicea*, Bedd.

Frequent in the higher sholas. Naimakad Gap, Karankulam, Perumalai, Anaimudi sholas, Silent Valley, Arivikad, Kandale Valley. 410, 1713. Fl. September. (Pulneys) Capsules contain 4 or 5 seeds. Seeds compressed-spherical 2·5–3 mm. long, light brown, surface furrowed.

35. *I. Wightiana*, Bedd.

In moist sholas. Devikolam, Kadalaar Valley, Anaimudi slopes. 610, 1683. Fl. September. (Anamalais)

36. *I. Tangachee*, Bedd.

Along streams on the slopes of Anaimudi, 7–7,500 ft. Fl. May, September, December. Near Perumalai. 504–9. 1684. Fl. September, December. (Anamalai and Bolumpatti Hills)

37. *I. platyadena*, C. E. C. Fisch. (Kew Bull. 1934, p. 393).

In evergreen forest and wet sholas. Kadalaar Valley, Naimakad Gap. 1677. Fl. September. Type in Kew Herb.

A NEW FIXATIVE FOR PLANT SMEARS

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During the course of an attempt to study meiotic chromosomes in *Rhoeo discolor* Hance considerable difficulty was experienced in getting satisfactory preparations. It was found that both medium Flemming's solution, and a slightly modified chromic-osmic-acetic solution, which gave satisfactory results with *Rhoeo* root tips failed to give good meiotic figures. Study of literature on the subject showed that adequate fixation is still treated as a problem. Baker (1) in his hand book takes such an attitude. Also there is no unanimity amongst cytologists as to the value of any particular formula. Guided by the researches of Zirkle (10) some new fixatives were tried. The general results of the experiments are given below and the points of interest are discussed.

The most successful technique with the smears may be taken first. The anthers in the proper stage of division were placed on a clean slide and excised with a razor blade. The pollen mother cells were pressed out and smeared with flat needle. The slide was immediately inverted in a dish containing a 2·5 per cent. solution of Merck's sodium-uranium-acetate. Cleanliness of the slide was found important for otherwise the cells did not adhere to the slide. Excising the anthers before pressing was found desirable as undue pressure in smearing gave rise to artifacts. The slide was kept in the solution for about 2 hours and washed with five or six changes in tap water. The slide was then carried upto 70 per cent alcohol through stages of 10, 20, 30 and 50 alcohol strengths. The slide was kept in 70 per cent alcohol at least overnight after which it was ready for staining. Crystal-violet, stained by Newton's method, gave exceptionally brilliant stain. Bleaching before staining was found unnecessary. The cytoplasm destained completely, the chromosomes retained stain even after destaining for five minutes and nucleoli stained lightly. It was found that 60 to 90 minutes of washing was optimum, as further washing made the stain to diffuse and briefer washing prevented staining. Hardening with 70 per cent alcohol was necessary for otherwise the cells were plasmolysed during staining. Fig. I is a photomicrograph of cells of *Rhoeo* fixed by this method. The strengths of fixative could be altered within small limits (from 2-3 per cent) without much altering its

effectiveness and, therefore, it was possible to use the same solution repeatedly. The only precaution necessary for its use is that it should not be exposed to direct sunlight as such a strong light has a photolytic action.

The particular solution was arrived at after an extensive series of trials. Zirkle had used a solution of uranium oxide in a particular strength of acetic acid, keeping the solution at a constant degree of acidity. A study of chemistry of uranium showed that such a procedure introduced complications. When uranium salt itself was utilised new complications arose owing to two reasons. The first was that different samples of uranium acetate were not of identical chemical constitution. The second was that three different plant materials used for testing, *Tradescantia, Hyacinthus* and *Tulipa* differed in their reaction to a solution. The difference between samples was due to the fact that uranium being a by-product of radium industry, unless specially purified carries sodium compounds as an impurity. It is possible that uranium acetate itself is a mixture of three different compounds, uranic, uranyl and uranous acetates. The specially purified uranyl acetate used in analytic chemistry when tried gave bad results with *Tradescantia,* passable results with *Tulipa* and *Hyacinthus.* Owing to practical difficulties, like colour of the solution, poisoning of electrode, and photoreduction, the H-ion concentration of the 2·5% solution could not be determined. Fresh trials were made with the pure uranyl salt, in which solutions were more or less acid by addition of acetic acid and sodium acetate respectively. Addition of 0·5 per cent by volume of acetic acid appreciably improved the meiotic figures in *Hyacinthus.* Addition of 1·0 per cent (by weight) of sodium acetate very much improved the fixation in all the plant material used. As a next step the Merck's purified compound sodio-uranium-acetate was tried which gave results mentioned above.

While fixing, the following feature was noticed. While unfixed cells are optically homogenous, fixed cells show internal differentiation, the stage of division can be made out. The chromosomes take up a light yellow colour while the cytoplasm is uncoloured. The colour presumably indicates that there is a preferential absorption of uranium. The colour is not completely removed by washing and this mordanting may be responsible for the very clear staining.

The retention of fixative may also be responsible for the gradual fading of preparations stained with crystal violet. The fading is gradual, the different batches varying widely in the rapidity of fading. Photograph II is that of a four year old preparation which had retained some details. The fading may also be due to other causes like defective Canada balsam, defective stain or exposure to light.

The main reason why extensive trials were made with uranium acetate was the occasional excellent results obtained

with its use. Photomicrograph III is that of the prophase of *Tradescantia virginica* fixed with this solution. In spite of loss of details due to fading the figure shows the excellence of the new fixation. From a reference to literature Darlington (2), Koller (5), Nebel (8) it appears that this stage has not been fixed adequately before with other fixatives. Also the price of the compound is not too high to be prohibitive; 4 oz. (120 gms.) cost about 8 shillings. Delicacy of action is also good. It has been possible to obtain evidence for two orders of spirals in meiotic chromosomes of *Hyacinthus*, structures which have been recently confirmed by Naithani (7).

There are two features of interest which were noticed during the course of study; the first is the possibility of improving the fixative by adding other compounds. The second is the possibility of using this as a tool in investigations on the manner of action of fixatives and their reliability.

Regarding the first feature there is a good case to be made out as to the urgent necessity of the improvement of plant fixatives. It can be asserted that finer preparations will be of great help in plant karyology.

In the study of meiosis in plants there are two structures which offer difficulty in interpretation, difficulties mainly due to the prevalent technique in fixation. One such problem is, "Are the two chromatids of a meiotic first metaphase chromosome closely fused together or distinctly separate from each other"? Kuwada (6) drew attention to this problem as early as in 1927 and inferred that in *Tradescantia virginica*, chromatids are closely united. In spite of this Darlington (2) (1932) states, "The metaphase chromosome whether at meiosis or mitosis consists of two rods, the chromatids, which are distinctly separated at an earlier stage and must be derived from the contraction of two separate threads." Clear visual and photographic evidence of the actual condition in different plants can best be obtained by better preparations. The other problem is, "In the paired chromosomes at Diplotene do all the points of contact between partners signify chiasmata"? Newton (9) implies in his paper on *Tulipa* that only some points of contact are chiasmata and the rest are not. Such differences are not implied by the later publications on *Tulipa* by Darlington and others (3, 4.) a backet Present preparations were not good enough to decide one way or the other and improved fixation would settle the question.

Considerable number of experiments were made in an attempt to improve the fixation mainly by the addition of various compounds to the solution. These compounds were formalin, chromic acid, chromic and osmic acids, glycine, ammonium carbonate, urea, maltose and potassium bichromate. Because these experiments were done haphazardly no important conclusion may be drawn. But the results obtained with the addition of formalin suggest that a suitable combination may be

evolved. Addition of 0·5% of chromic acid to the fixing solution may be of use with some plants. Also it appears that for best results fixative formula should be different for different plants.

Regarding the second feature of interest with the uranium acetate fixative, the facts of observation are as follows: When a smear is inverted in the fixative, the fixation does not take place immediately. Under the low power of the microscope the time taken for the fluid to coagulate cell structures can be observed. While with sodium-uranium-acetate solution the coagulation takes place in 30 seconds, the interval is greater with some other fluids, *e.g.*, solution made alkaline with ammonium carbonate. This time lag can be used to study the rate of killing of new combinations. The time lag is very important, for it is our experience, and also probably that of others, that wherever the fixation is slow the nuclear structures are badly preserved. Any new combination which does not fix rapidly may be considered unsuitable. Theoretically use of adjuvants like urea should reduce the time taken for the fixative to enter the cells. Whether such a quickening does take place in case of smears, can be detected visually with the new fixative.

In the fixed unstained preparations it appears as if the chromosomes are different in texture from the rest of the cytoplasm. To verify this inference, the preparations were studied under darkground illumination. Fig. IV is the photograph of unstained *Rhoeo* pollen mother cells mounted in water, fixed by sodio-uranium-acetate and illuminated by darkground condenser. The figure shows that the nucleus is structurally different from the cytoplasm, presumably so differentiated by the fixative. As the smears are unstained, the darkground illumination would differentiate only where there is a difference in texture and/or refractive index between nucleus and cytoplasm. It is possible that the physical change accompanying fixation may be responsible for the differential staining of cytoplasm and nucleus. This is mentioned as a possibility and not a probability. The relevancy of this possibility is as follows. There is a considerable interest for the cytologists in the cause of the specificity of staining. Research has been done in this subject. Baker (1) refers to some of the results of the research. In an investigation on the specificity of staining of plant chromosomes to find out whether it is due to chemical affinity, or physical texture, or a combination of both, the new fixative and use of darkground illumination will be of use.

Summary

A 2·5 per cent. solution of sodium-uranium-acetate is recommended as a fixative for pollen mother cell smears. The cells are to be fixed for about two hours, washed for about an hour and hardened in alcohol before staining.

There is a possibility that the fixative can be improved by the addition of other compounds like formalin and chromic acid.

A certain amount of uranium is preferentially absorbed by chromosomes and this feature may be of use in a research on the nature of fixation.

The fixative coagulates the cytoplasm differentially from the nucleus and this feature may be of use in a research on the nature of staining.

Literature Cited

1. BAKER, J. R.—(1933) Cytological Technique. London.
2. DARLINGTON, C. D.—(1932) Recent Advances in Cytology. London.
3. ———— and E. K. J. Ammal—(1932) The origin and behaviour of chiasmata I. Diploid and tetraploid *Tulipa*. Bot. Gaz. 93, 296—311.
4. ———— and K. Mather—(1932) The origin and behaviour of chiasmata III. Triploid *Tulipa*. Cytologia 4, 1-15.
5. KOLLER, P. CH.—(1932) Further studies in *Tradescantia virginiana* var. *humilis* and *Rhoeo discolor*: Jour. Gen. 26, 92-94.
6. KUWADA, Y.—(1927) On the spiral structure of chromosomes. Bot. Mag. Tokyo 41, 100-109.
7. NAITHANI, S. P.—(1937) Chromosome studies in *Hyacinthus orientalis* L. II. Ann. Bot. N. S. 1.
8. NEBEL, B. N.—(1932) Chromosome structure in Tradescantiæ I and II. Ztschr. für Zellforsch u. Mikr. Anat. 16.
9. NEWTON, W. C. F.—(1927) Chromosome studies in *Tulipa* and some related genera. Jour. Lin. Soc. (Bot.) 47, 339-356.
10. ZIRKLE, C.—(1929) Fixation images with chromates and acetates. Protoplasma 5, 511-534.

Explanation of Plate V

Fig. I. Smear of *Rhoeo* pollen mother cells.

Fig. II. Smear of *Tulipa* pollen mother cells in the first division metaphase stage.

Fig. III. Single prophase nucleus of *Tradescantia virginica*.

Fig. IV. Smear of *Rhoeo* pollen mother cells under dark ground illumination.

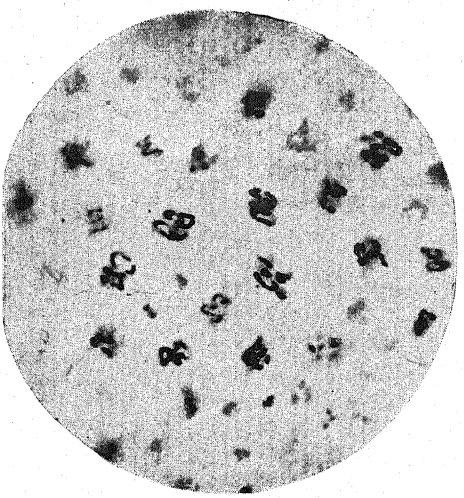

Fig 1

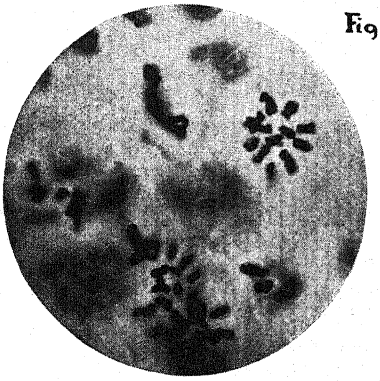

Fig 2

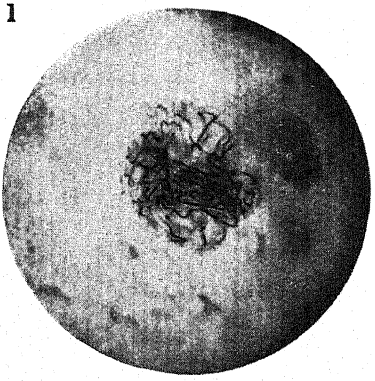

Fig 3

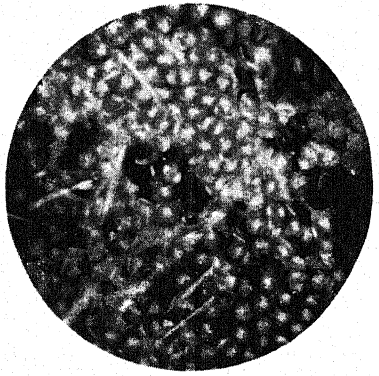

Fig 4

B. N. SINGH. S. SAMPATH and R. K. BANSAL—
A NEW FIXATIVE FOR PLANT SMEARS

STUDIES IN THE SOIL FUNGI OF THE PADDY-FIELDS OF BENGAL

I. Fungi of an unmanured paddy-field of the Chinsurah Agricultural Farm

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Introduction

Extensive work on various aspects of the fungus flora of the soil has been done in Europe, America and other countries abroad, but so far very few workers have studied the soil fungi and their activities in this country. Amongst the Indian workers names of Butler (2), Shaw (19), Thukur and Norris (23), Chaudhuri (5), Chaudhuri and Sachar (4), Chaudhuri and Umar (6), Hukumchand (15); Galloway (14); and Mason (16) may be mentioned.

A general review of the results of the various workers in this country and abroad shows that the activities of the soil fungi are manifold and probably they play an important role in the processes of soil fertility.

As paddy is one of the principal crops of Bengal, the present workers intend to make a comparative study of the fungal flora of the paddy fields in the different districts and their relation to soil fertility if any.

The present work deals mainly with the systematic study of fungi of an unmanured paddy field at Chinsurah Agricultural Farm near Calcutta.

Experimental

Soil samples were taken from the Chinsurah Agricultural Farm on 10th December, 1937, from Block A, plot no. 27-A. The plot was left unmanured for the previous five years and covers an

area of 0·2 acres of land. Paddy was grown in the plot for several years without any rotation of crops and the yield in 1937 was 6 mds. 23 srs. 12ch. only. The object of choosing the agricultural farm was that it could give us the best possible scientific data.

Samples were taken up to a depth of 6 inches, scraping off half an inch from the surface, but the authors concentrated their attention mainly up to 4th inch, as the largest number of fungi were found within 1 to 4 inches from the surface. Beyond the 4th inch, fungal centents suddenly decreased. Samples were removed by means of a wide borer, and samples of different depths were separately placed in well sterilized glass jars.

Another set of samples was taken by pit method, *i.e.*, by digging out the desired place upto one foot and on one vertical side the depth was marked off with a scale from first to sixth inches, starting from the surface downwards and the samples from each inch were scraped out by means of a spatula in different glass jars. The containers with samples were subsequently brought to the laboratory. A portion of the samples was first removed for the determination of moisture and pH. value and the rest was rubbed through a well sterilized sieve of wire-mesh, well mixed together and finally stored in well stoppered sterile glass jars for examination.

The fungi were isolated both by dilution and direct inoculation method. Dilutions were made upto 10000 with sterile distilled water. 5 cc. of this diluted suspension with modified albumen agar was poured in each Petri dish. The plates were incubated at 28°C for about a week. The fungi isolated from the plates were transferred to Resin agar and finally to Czapek's synthetic medium.

In the direct inoculation method, Petri dishes with modified albumen agar were inoculated with samples and incubated for 3 days at 28°C. Mycelia developed from such inoculations were immediately transferred to Resin agar. Further examinations were made on Czapek's medium as before.

Moisture content and pH values of different depths were carefully determined with soils from various region of the same plot. The pH value from 1" to 6" differed little (5·9—6·0), but the percentage of moisture decreased gradually (17% to 12·6%) excepting at 4" depth where the percentage of moisture was found as high as in the top layer.

The following shows the list of the fungi isolated from the different depths (in inches) of the paddy field.

It will be seen from the above table that the species and number of fungi gradually decreased from the top to the third inch. At 4th inch, which contain a high percentage of soil moisture, the type and number of fungi suddenly increased and then again gradually decreased till to the 6th inch where the soil fungi finally disappeared.

TABLE I.

List of the fungi isolated from the different depths (in inches) of the Paddy-field.

NAME OF THE ORGANISM.	Depth of the soil in inches.					
	1	2	3	4	5	6
1. *Mucor racemosus* Fres. ..	—	+	—	+	—	—
2. ,, *hiemalis* Wehmer ..	+	—	—	+	—	—
3. *Rhizopus nigricans* Ehrenb. var. *minutus* ..	+	+	—	+	+	—
4. *Rhizopus* sp. no. 1 ..	—	—	—	+	—	—
5. *Cunninghamella verticillata* Paine ..	—	—	—	+	—	—
6. *Aspergillus niger* Van Tieghem.	+	+	—	+	+	—
7. ,, *glaucus* group ..	+	—	—	—	—	—
8. ,, *fumigatus* Fres. St. A. ..	+	—	+	+	+	—
Aspergillus ,, ,, St. B. ..	+	+	—	+	—	—
Aspergillus ,, ,, St. C. ..	—	—	—	+	—	—
9. ,, *sulphureus* (Fres.) Thom & Church ..	—	—	—	+	—	—
10. ,, sp. no. 1 ..	—	—	—	+	—	—
11. ,, sp. no. 2 ..	—	—	—	+	—	—
12. ,, sp. no. 3 ..	—	—	—	+	—	—
13. ,, *niger* group ..	—	—	—	+	—	—
14. ,, *sydowi* (Bainier & Sartory) Thom & Church ..	—	—	—	+	—	—
15. *Penicillium terrestre* Jensen ..	—	—	—	+	—	+
16. *Fusarium dimerum* Penz. ..	—	+	—	—	—	—
17. ,, *orthoceras* Ap. et. Wr.	—	—	—	+	—	—
18. ,, sp. no. 1 ..	+	—	—	—	—	—
19. ,, sp. no. 2 ..	—	+	+	+	—	—
20. ,, sp. no. 3 ..	—	+	—	+	—	—
21. ,, *oxysporum* Schlecht ..	+	+	—	—	—	—
22. ,, *solani* (Mart) Ap. et. Wr. ..	—	—	+	—	—	—
23. Sterile white mycelium ..	—	—	—	+	—	—

N.B. + represents presence of the fungi.
— denotes their absence.

Description of species

1. **Mucor racemosus** Fres.

Colony light grey, mycelium cobwebby with black sporulation, hypha coarse, unseptate, 12-20 μ thick. Sporangiophore, unbranched when young but branched when old, 14 μ broad and 720-864 μ in length. Sporangia varying greatly in size, globose, yellow-brown, 80-132 μ in diameter. Columella globose to oval 24-30 $\mu \times$ 30-90 μ. Spores globular to oval, smooth 4 to 4·5 $\mu \times$ 6 μ. Chlamydospores numerous, singly or in chains, spherical, 20 μ in diameter. No sexual reaction.

Also reported by Adametz in Germany, Lendner in Switzerland, Hagem in Norway, Dale in England, Jensen in Long Island, Mclean, Wilson and Waksman in New Jersey, Thakur and Norris from Bangalore (description not given).

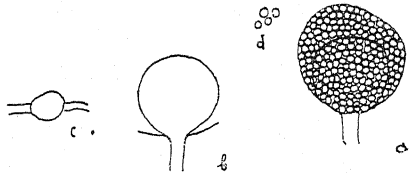


Fig. 1. *Mucor racemosus* Fres. (*a*) Single sporangium (× 192½), (*b*) Columella showing Collar (× 192½), (*c*) Chlamydospores in vegetative mycelium (× 192½), (*d*) Spores (× 192½).

2. **Mucor hiemalis** Wehmer

Colony light grey, turning lead grey to brown. Sporangiophore erect, unbranched, varying in length from 360 μ to 1·2 m.m.

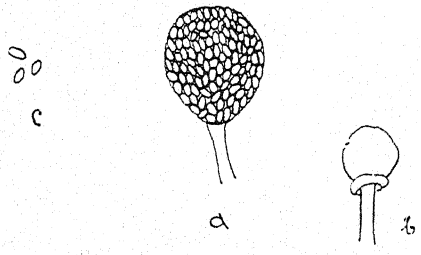


Fig. 2. *Mucor hiemalis* Wehmer (*a*) Single sporangium (× 288¾), (*b*) Columella (× 288¾), (*c*) Spores (× 288¾).

Sporangia yellow-brown with a slight tinge of light green, globose, 48 to 78 μ in diameter. Sporangial wall dissolving, columella globose to oval 32 to 40 μ high and 32 to 36 μ broad. Chlamydospores numerous, round to barrel shaped, 12-20 $\mu \times 14\ \mu$.

Reported by Hagem in Norway, Lendner in Switzerland, Namyslowski in Austria, Jensen in Ithaca, Mclean, Wilson and Waksman in New Jersey.

3. **Rhizopus nigricans** Ehrenb. var. **minutus**

Chaudhuri and Sachar (1932), Thakur and Norris (1928), Galloway (1936) Hukumchand (1937).

4. **Rhizopus** Sp. No. 1.

Colony white, turning black at maturity with sporulation, growth cobwebby. No rhizoid was found. Sporangiophore mostly in a group of two, 200-500 μ in length; breadth being 8 μ in the middle and 14 μ at the base, sporangiophore never forked, ending in a globose sporangium 140 μ in diameter. Spores globose to oval 5-6 $\mu \times$ 4-5 μ.

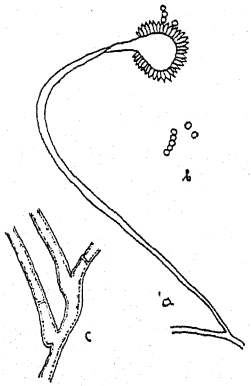


Fig. 3. *Rhizopus* Sp. No. 1. (*a*) Sporangiophores without rhizoids at the node (× 50), (*b*) Spores (× 192½).

5. **Cunninghamella verticillata** Paine

Chaudhuri and Sachar (1932).

Isolated from alkaline soil, Lahore.

6. Aspergillus niger van Tieghem

Thom and Church (1926), Chaudhuri and Sachar (1932), Galloway (1936), Thakur and Norris (1928), Chaudhuri and Norris (1928), Mason (1928).

Isolated from soil and air.

7. Aspergillus glaucus Group.

Colony greyish green with white colour at the periphery; mycelium septate, branched; hyphae 4 μ thick. Conidiophore erect, unbranched, wall smooth, unseptate 440-680 μ in length and 8 μ in breadth, diameter of the vesicle 60 μ, globose; sterigmata in one series. Perithecia unknown. Conidia globular to oval, smooth, appears greyish green in a mass, 4-6 $\times$ 6 μ.

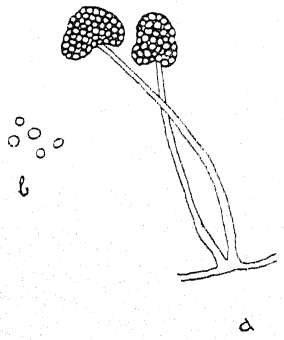


Fig. 4. *Aspergillus glaucus* Group (*a*) Conidiophore with vesicle and Sterigmata ($\times$ 120), (*b*) Spores ($\times$ 2883/4).

8. Aspergillus fumigatus Fresenius

Thom and Church (1926), Butler (1917), Chaudhuri and Sachar (1932), Chaudhuri and Umar (1935) Finlow (1918), Galloway (1936) and Thakur and Norris (1928), Chaudhuri and Umar (1938).

Isolated from soil and air.

Strain A.—Chaudhuri and Sachar (1932).
Isolated from field, garden and alkali soils of Lahore.

Strain B.—Chaudhuri and Sachar (1932).
Isolated from humus soil, Lahore.

Strain C.—Colony niagaragreen, reverse no change. Mycelium septate, branched, vegetative hyphae 4 μ thick. Conidiophore unbranched, unseptate, more or less erect, 160-192 μ high and 4-6 μ broad, ending in a flask shaped vesicle 16-20 μ in diameter. Sterigmata in one row covering the whole of the vesicle. Conidia hyaline, 2-3 μ.

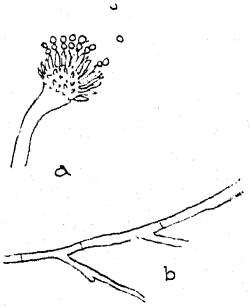


Fig. 5. *Aspergillus fumigatus* Fres. (*a*) Head with spores (× 288¾), (*b*) Vegetative hypha (× 288¾).

9. **Aspergillus sulphureus** (Fres.) Thom and Church

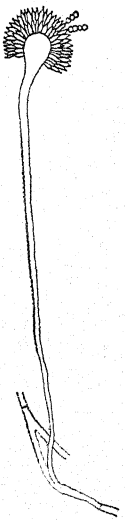


Fig. 6. *Aspergillus sulphureus* (Fres.) Thom and Church (*a*) Conidiophore with sterigmata and spores (× 192½).

Thom and Church (1926), de Mello (1920), Chaudhuri and Umar (1938).

Isolated from Laboratory contamination.

10. Aspergillus Sp. No. 1.

Colony citrene yellow, reverse colourless. Mycelium septate, branched, sometimes swollen at the nodes. Vegetative hypha 3.5 μ thick; conidiophores small, erect, generally unseptate but septation appears in old ones, 208-280 μ high and 4 μ broad, gradually enlarging upwards in a flask shaped vesicle 20-28 μ in diameter. Conidiopore just below the vesicle 8 μ broad. Sterigmata covering only half of the vesicle at the top in one row. Conidia globular to slightly oval, 4 μ to 4 $\times$ 6 μ, hyaline.

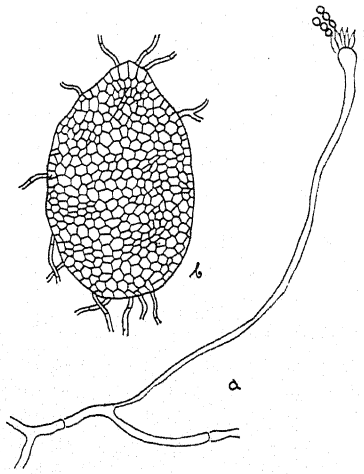


Fig. 7. *Aspergillus* Sp. No. 1. (*a*) Conidiophore with sterigmata and spores ($\times$ 192½), (*b*) Perithecia ($\times$ 23).

11. Aspergillus Sp. No. 2.

Colony snuff brown, reverse unchanged. Conidiophores erect, unbranched, with thin septation, 260-360 μ high and 6-8 μ broad. Vesicle globular or slightly oval 8 μ or 8 $\times$ 12 μ. Sterigmata in one row, very big in comparison with the vesicle, 8-12 μ in length and 2-3 μ broad. Conidia 4-6 μ adhering to form chains.

This species of Aspergillus was found to be more allied to *A. Calyptratus,* also found by Oudemens but differs to a certain

extent in measurements of Conidia and sterigmata. The description given by Oudemans seem to be inadequate.

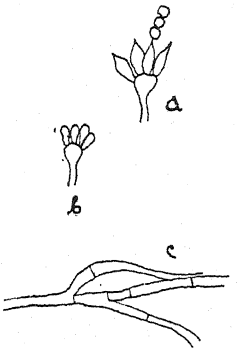


Fig. 8. *Aspergillus* Sp. No. 2. (*a*) Head with spores (× 288¾), (*b*) Head with young sterigmata (× 288¾), (*c*) Vegetative hypha (× 288¾).

12. Aspergillus Sp. No. 3.

Colony olive grey to brown, reverse no change. Mycelium septate, branched, hyphae 4 to 4·5 μ thick. Conidiophore nonseptate, erect, unbranched, 88-112 μ long or sometimes as long as 268 μ and 4-4·5 μ broad; vesicle globose to flask shaped, sometimes bifurcated. Sterigmata in one row, few in number and only at the top of the vesicle, comparatively big, 16 × 4 μ. Some of those sterigmata undergo proliferation to produce secondary conidiophores, each with a smaller vesicle on the top. On further development conidiophores of the third order arise by prolongation of a few of

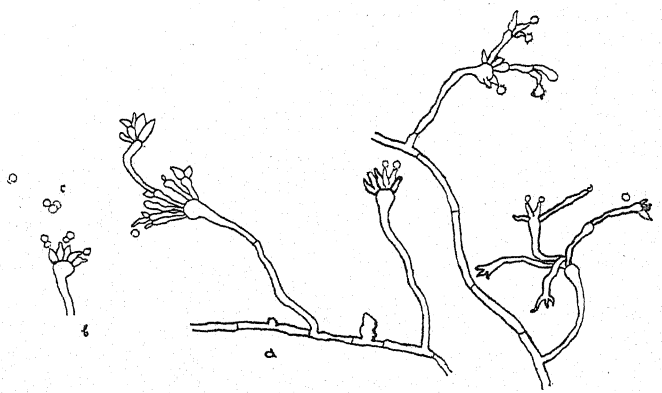


Fig. 9. *Aspergillus* Sp. No. 3. (*a*) Hypha bearing primary, secondary and tertiary Conidiophores (× 192½), (*b*) Head with sterigmata and spores (× 192½), (*c*) Spores (× 192½).

the sterigmata borne on the secondary vesicles. These tertiary conidiophores bear still smaller vesicles possessing 3 to 5 sterigmata.

The primary vesicles are globose to flask shaped, 16 μ in diameter; the secondary vesicles are slightly swollen at the top, 9 μ in diameter and the tertiary vesicles smaller still, 4·5 μ in diameter. Conidia globular, hyaline when young but light brown when old, with echinulations, 4-6·5 μ arranged on longer conidiophores in chain, forming a cone.

The authors could not place it with any known form.

13. Aspergillus niger group.

This particular type differs from *A. niger* van Tieghem in the length of conidiophores. Colony carbonaceous black, substratum slightly crumpling and turning to some shades of yellow. Conidiophore erect, unseptate, 400-428 μ high and 8 μ broad, ending in a globose vesicle 26-32 μ in diameter. Sterigmata in two rows all over the vesicle. Conidia globular, smooth, 4 μ.

14. Aspergillus sydowi (Bainier and Sartory) Thom and Church.

Thom and Church (1926), Chaudhuri and Sachar (1932), Chaudhuri and Umar (1935), Galloway (1936), Chaudhuri and Umar (1938).

Isolated from soil and air.

15. Penicillium terrestre Jensen.

Thom (1930), Chaudhuri and Sachar (1932).

Isolated from Garden and field soil, Lahore.

16. Fusarium dimerum Penz.

Colony white, velvety, does not turn Brown's or Czapek's medium yellow; chains of barrel shaped Chlamydospores intercalary

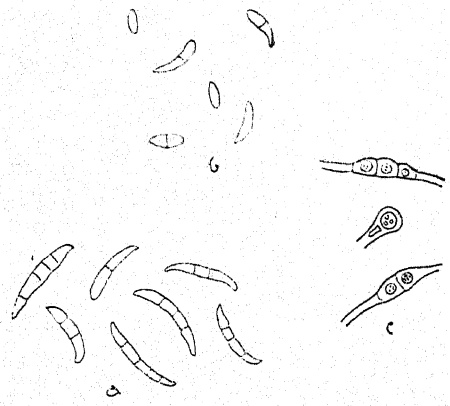


Fig. 10. *Fusarium dimerum* Penz. (*a*) Macroconidia (× 288¾), (*b*) Microconidia (× 288¾), (*c*) Chlamydospores (× 288¾).

or terminal, generally in a group of 2 to 4 or sometimes single. Vegetative hyphae 2-2·5 μ thick. Macroconida sickle shaped, or linear, 1-3 septate, 14-20 μ $\times$4 μ.

17. Fusarium orthoceras Ap. et. Wr.

Colony white, fluccose, vegetative hyphae septate, 3 μ in diameter. Chlamydospores terminal, globular 8 to 12 μ in diameter or elliptical, 6 $\times$ 12 μ. Conidia with delicate wall, microconidia and macroconidia are present. Microconidia generally cylindrical, usually unicellular 2-6 $\times$ 8-12 μ, sometimes with one septum, 4-6 $\times$ 16-20 μ, mostly 4 $\times$ 16 μ. Macroconidia sickle shaped, 2 to 3 septate, tapering at both ends, usually 3·5-4 μ $\times$ 28-31 μ.

Also reported by Waksman from New Jersey.

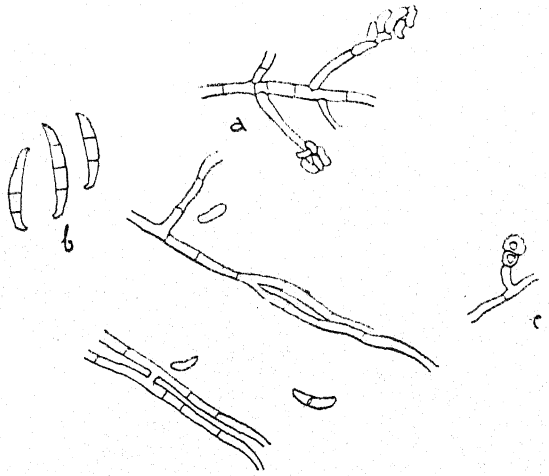


Fig. 11. *Fusarium orthoceras* Ap. et. Wr. (*a*) Hypha bearing microconidia ($\times$ 288¾), (*b*) Macroconidia ($\times$ 288¾), (*c*) Chlamydospores ($\times$ 288¾).

18. Fusarium Sp. No. 1.

Colony white; Chlamydospores growing profusely, intercalary or terminal, when intercalary generally 2-4 cells in a chain, sometimes 1 celled. Macroconidia and Microconidia are both present. Macroconidia 1 to 4 septate, 3 septate 5 $\times$ 22 μ, 4 septate 5 $\times$ 30 μ.

Microconidia generally nonseptate, sometimes 1 septate one end round and the other tapering, 4 × 6-8 μ.

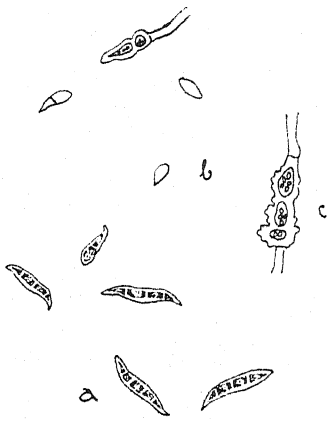


Fig. 12. *Fusarium* Sp. No. 1. (*a*) Macroconidia (× 288¾), (*b*) Microconidia (× 288¾), (*c*) Chlamydospore (× 288¾).

19. **Fusarium** Sp. No. 2.

Colony white, velvety. Mycelium septate, branched, vegetative hyphae 3 μ thick. Chlamydospores oval to globular, terminal, sometimes intercalary, 8-12 × 8-20 μ, mostly 8 × 12 μ. Perithecia flask shaped with a small neck, 245-486 μ × 318-432 μ. Asco-

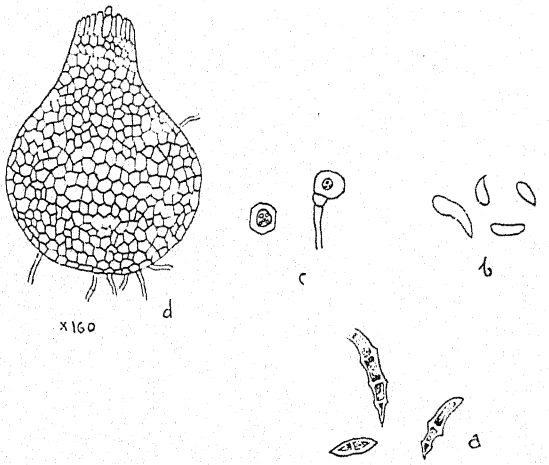


Fig. 13. *Fusarium* Sp. No. 2. (*a*) Macroconidia (× 288¾), (*b*) Microconidia (× 288¾), (*c*) Chlamydospore (× 288¾), (*d*) Perithecia (× 120).

spores globular 6 to 10 μ in diameter. Macroconidia sickle shaped to linear, 1-5 septate, tapering towards both ends, 1 septate, 8-14 μ × 2·5-4 μ; 2 septate 16 × 4 μ; 3 septate 18-32 μ × 3·5-4 μ; 4 septate 24 × 3·5-4 μ; 5 septate 30-32 μ × 4 μ.

20. Fusarium Sp. No. 3.

Colony white, velvety; mycelium branched, septate; vegetative hyphae 3·5 μ thick; chlamydospores terminal. Microconidia thin walled, non-septate, one end broader and the other tapering, 8-10 μ × 4 μ. Macroconidia spindle shaped, tapering at both ends, upto 2 septate, 24-28 μ × 4-4·5 μ.

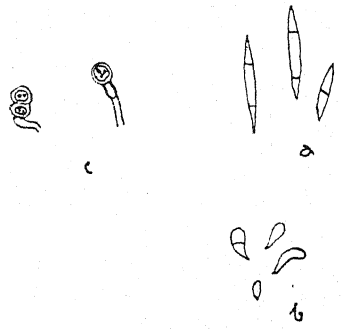


Fig. 14. *Fusarium* Sp. No. 3. (*a*) Macroconidia (× 288¾), (*b*) Microconidia (× 288¾), (*c*) Chlamydospores (× 288¾).

21. Fusarium oxysporum Schlecht.

Chaudhuri and Sachar (1932).

From field soil, Lahore.

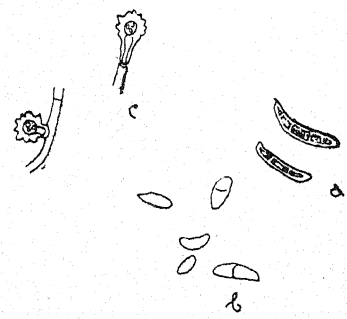


Fig. 15. *Fusarium oxysporum* Schlecht (*a*) Macroconidia (× 288¾), (*b*) Microconidia (× 288¾), (*c*) Chlamydospore (× 288¾).

22. Fusarium solani (Mart) Ap. et. Wr.

Colony white, velvety; vegetative hyphae septate, branched; macroconidia and microconidia both present. Macroconidia 1-3 septate, sickle shaped, tapering at both ends, 1 septate 5 μ × 28 μ; 3 septate 4 × 12-22 μ.

Reported by Waksman in New Jersey and Dale in England.

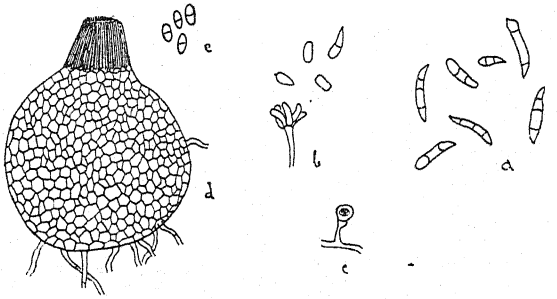


Fig. 16. *Fusarium solani* (Mart.) Ap. et. Wr. (*a*) Macroconidia (× 192½), (*b*) Microconidia in Situ (× 192½), (*c*) Chlamydospore (× 192½), (*d*) Perithecia (× 80), (*e*) Ascospore (× 80).

23. Sterile white mycelium

Galloway (1936).

Isolated from soil.

Reference

1. Butler, E. J. and Bisby, G. R.—The Fungi of India, Calcutta, 1931.

2. Butler, E. J.—"An account of the genus Pythium and some Chytridiaceae." Mem. Dept. Agr. Ind. Bot. Ser., 1907, No. 5, I : I-160, pl-10.

3. Clements, F. C. and Shear, C. L.—1931. The genera of fungi.

4. Chaudhuri, H. P. and Sachar, G. S.—1934. "A study of the fungus flora of the Punjab soil." Ann. Mycol. Vol. XXXII.

5. Chaudhuri, H.—1938. Molds of the Punjab II. The Penicillia. Proc. Ind. Acad. Sci. Sec. B, Vol. VIII, No. 2.

6. CHAUDHURI, H. and UMAR, M.—1938. Molds of the Punjab I. The Aspergilli. Proc. Ind. Acad. Sci. Sec. B, Vol. VIII, No. 2.

7. ————1935. "On some Aspergilli and Penicillia." Proc. Ind Sci. Cong. Calcutta.

8. COOKE, M. C.—"Some Indian fungi" ibid., 1878, 6.

9. COLEMAN, D. A.—1916. "Environmental factors influencing the activity of soil fungi." Soil Science.

10. DALE, E.—1912. "On the fungi of the soil." Ann. Mycol. Bd. 10.
1914. "On the fungi of the soil." Ann. Mycol. Bd. 12.

11. DE MELLOW, F.—1920. "Contribution to the study of Indian Aspergilli" Jour. Ind. Bot., 1920, I.

12. ENGLER, A. and PRANTL, K. A.—1897. Die naturlichen Pflanzen familien.

13. FITZPATRIC, H. M.—The lower fungi-Phycomycetes.

14. GALLOWAY, L. D.—1936. "Indian soil fungi." Ind. Jour. Agri. Sci.

15. HUKUMCHAND.—"Study of the fungus flora of Lahore soil." Proc. Ind. Acad. Sci. Vol. V, No. 6, Sec. B.

16. MASON, E. W.—"Annotated account of fungi received at the Imperial Bureau of Mycology." List, 1928, 2.

17. MAHJU, A. N.—"A contribution to our knowledge of Indian Coprophilous fungi." Journ. Ind. Bot. Soc. 1933, 12.

18. RIDGWAY, R.—1912. Color Standards and Color nomenclature.

19. SHAW, F. J. F.—1915. Pusa Annual Report, 1914-15.

20. SACCARDO.—Sylloge fungorum.

21. THOM, C.—The Penicillia, 1930.

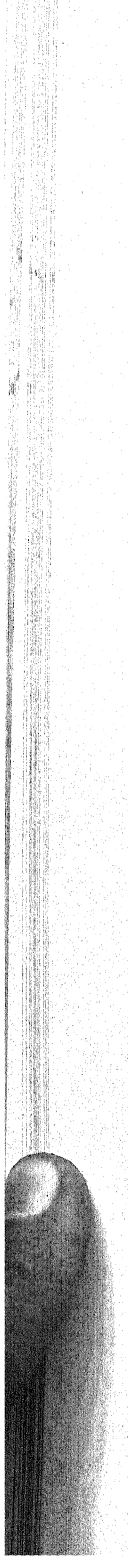
22. THOM, C. and CHURCH, M. B.—The Aspergilli, Baltimore, 1926.

23. THAKUR, A. K. and NORRIS R. V.—A biochemical study of some soil fungi with special reference to ammonia production. Jour. Ind. Inst. Sci. XI, A, 12, 1928.

24. WAKSMAN S. A.—1916. Soil fungi and their activity. Soil Science.

25. WOLLENWEBER, H. W. and REINKING, O. A.—1935. Die Fusarium.

26. ZYCHA, H.—1935. Kryptogamen flora der Mark Brandenburg. Pilze II (Mucorineae).



SOME DOMINANT PLANTS OF INDIA

BY

D. CHATTERJEE, M.SC. (Cal.), PH.D. (Edin.), F.L.S. (Lond.), F.R.H.S. (Lond.).

[*Communicated by K. Biswas*]

Received for publication on 26th September, 1939

Hooker's review of the various families of plants as sketched by him in the Imperial Gazetteer of India, Vol. I., p. 167 (1907), demands considerable revision in the light of subsequent researches. A critical and statistical study of this was taken up by the writer while working in Edinburgh and in Kew during 1938, and it was found that modifications are necessary for the following reasons:—

Firstly, in addition to India proper Hooker's estimate was based on plants from Malaya, Ceylon and Tibet. These areas have distinct floras of their own and should be excluded. Secondly, during the last sixty years, more than 2,000 new species have been discovered in India and described. Many foreign plants have also been recorded from different parts of the country. The incorporation of these considerably alters the specific contents of families and genera of the Indian Flora as a whole. Although botanically many parts of Burma still remains *"terra incognita"*, quite a large number of species have been collected and described during the last few years. Consideration of these facts needs alteration in the composition of the dominant plant groups and the limits of their distribution.

The present arrangement of the Dicotyledonous families of India (according to the writer) is as follows:

Present arrangement (1939)	Total Number of species in India (1939)	Hooker's arrangement (1907)
1. *Papilionaceæ* .. [*Excluding* 127 *Sp. of Cæsalpiniaceæ* 96 *Sp. of Mimosaceæ*]	867	1st (Leguminosæ)

Present arrangement (1939)	Total Number of species in India (1939)	Hooker's arrangement (1907)
2. *Compositæ* ..	696	5th.
3. *Rubiaceæ* ..	551	2nd.
4. *Acanthaceæ* ..	514	4th.
5. *Euphorbiaceæ* ..	444	3rd.
6. *Labiatæ* ..	421	6th.
7. *Scrophulariaceæ* ..	273	These positions have not been indicated in Hooker's account.
8. *Rosaceæ* ..	257	
9. *Balsaminaceæ* ..	242	
10. *Asclepiadaceæ* ..	234	
11. *Primulaceæ* ..	208	
12. *Gentianaceæ* ..	189	
13. *Umbelliferæ* ..	180	
14. *Cruciferæ* ..	178	
15. *Convolvulaceæ* ..	177	

The present estimation was made on species found in India proper and Burma (and excludes those from Ceylon, Malaya and Tibet). Hooker's sequence for the first six families is also indicated in the table above.

Compositæ play a very dominant part in the vegetation of many countries and Hooker expected that with more records of these from the Indian region the family would take a more prominent position as regards dominance, than the 5th place in his own reckoning. To-day we find that Hooker was correct in his anticipation. The *Papilionaceæ* exceed the *Compositæ* by a wide margin, and in a country like India the former will probably always hold the more dominant position. The 3rd place is occupied by the family—*Rubiaceæ*, which was second in Hooker's arrangement. One reason for the slight fall in position is perhaps the exclusion of the species from Malaya and Ceylon in our estimate, while they were included by Hooker. Even if we had followed Hooker and included all the species of *Rubiaceæ* from these areas it would be difficult to supersede the present high figure of *Compositæ*.

Acanthaceæ and *Labiatæ* have maintained their former positions, though they have received a significant number of additions during the period of the last thirty years. Other families which similarly have had considerable accessions are *Balsaminaceæ, Primulaceæ* and *Gentianaceæ.*

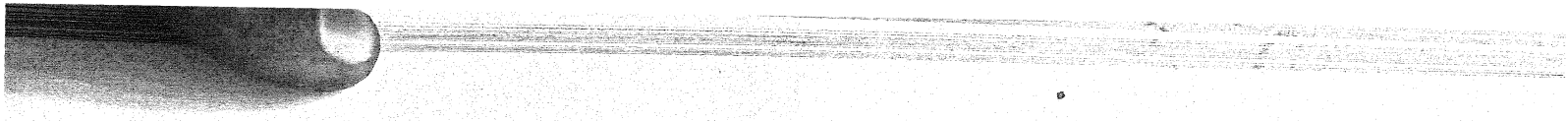
A considerable change has also taken place among the various Indian genera. Many genera have been broken up into smaller units according to our present conception of their limits. Mention may be made of *Ipomœa, Loranthus,* and *Eugenia.* Again on the other hand, considerable number of monotypic genera have been found. These have jointly resulted in the fall of the *genus-species ratio.* The proportion of genera to species is now 1 to 6 as contrasted to the previous figure of Hooker which is 1 to 7. Approximately 290 genera new to our area have been added to those recorded in Hooker's Flora of British India.

The largest genus in India *Impatiens* is undoubtedly. I give below a list of the 20 genera which have large number of species.*

Impatiens L. (241), Primula L. (162), Strobilanthes Bl. (152), Rhododendron L. (126), Eugenia L. (103), Crotalaria L. (99), Gentiana L. (93), Piper L. (89), Polygonum L. (87), Ficus L. (86), Pedicularis L. (76), Senecio L. (76), Oldenlandia L. (75), Begonia L. (71), Corydalis L. (61), Euphorbia L. (61), Astragalus L. (59), Saxifraga L. (58), Indigofera L. (53), Desmodium Desv. (52).

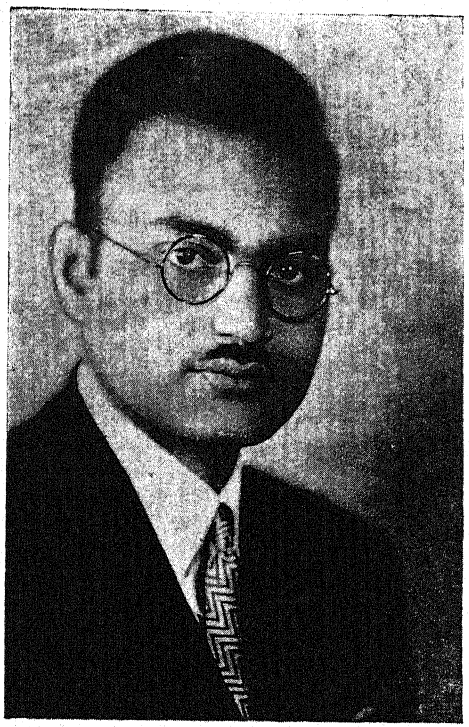
A survey of these larger genera appears to show that they represent families of the temperate region much more strongly than the tropical. Secondly, almost without exception they are genera of a very wide distribution. One of these genera only has an almost wholly Asiatic content, and that is *Strobilanthes Bl.* It is also interesting to record here that none of the families with the exception of *Papilionaceæ,* can claim more than one of these large genera.

* The list has been drawn up by the author and differs considerably from those previously made by other botanists. The number of species is indicated at the end of each genus.



Dr. P. N. GHATAK, M.Sc., Ph.D., D.I.C.

(1902—1939)



Dr. P. N. Ghatak, Assistant Lecturer in Botany in the Calcutta University died on the 13th July 1939 as the result of an illness contracted at Darjeeling during the last summer. He was brought down to Calcutta and was given the best medical aid but he suffered patiently and died peacefully.

Dr. Ghatak was the pink of courtesy in all his dealings. His magnetic personality, charming and amiable manners and his ever smiling face endeared him to all with whom he came in contact.

Dr. Ghatak was born in 1902 in the village of Hashail (Dist. Dacca) and was the third son of late Srinath Ghatak, a well-to-do and respectable gentleman of the district.

After completing his studies in the school he joined the Presidency College, Calcutta, and graduated with Honours in Botany in 1925 and passed his M.Sc. in 1927. In the same year

he was appointed the Lecturer-Demonstrator at the Presidency College and worked there till the middle of 1929, when he left India for further studies in England. He joined the Imperial College of Science and Technology, London, and studied Plant Pathology under Prof. V. H. Blackman and Dr. Tabor. He obtained his Ph.D. degree and D.I.C. diploma in due time. He then toured through the Continent and returned to India in 1933. After his return he was appointed Hony. Lecturer in Plant Pathology in the Calcutta University. Some time later he was appointed on the staff of the Rust Research Laboratory at Simla, under Rai Bahadur Dr. K. C. Mehta. He was appointed Asst. Lecturer in Botany, Calcutta University in September 1935 and continued to work in that capacity till the day of his death.

In May 1934 he married Sm. Gita Devi, B.A., the eldest daughter of Mr. Anurup Mookerjee of Allahabad. He leaves behind a daughter and his widow and two brothers to mourn his loss.

Both in the University and elsewhere he carried out original investigations. Some time ago Messrs. Barry & Co., Calcutta, approached him to eradicate the fungus which used to affect the oil cakes supplied by them to foreign countries. Dr. Ghatak studied the problem and submitted his suggestions after careful studies, which saved the company loss of several thousands of rupees. In the University he was investigating the storage rot of oranges. A list of his scientific contributions is given below.

1. Secondary growth in thickness in the roots of *Amorphophallus campanulatus* BL.—by. G. P. Mazumdar and P. N. Ghatak.—Proc. Ind. Sc. Congr. Madras, 1929.

2. On the development of the Perithecium of *Microeurotium albidum* Ann. Bot. Vol. L., 849-862, 1936. (A part of his Ph.D. thesis).

3. He established a new genus of fungus—the paper is in the Press, so far as I know (a part of his Ph.D. degree).

4. Investigations on the Storage Rot of oranges, I. Orange Rot due to two strains of *Fusarium moniliforme* Sheldon.—Journ. Ind. Bot. Soc. Vol. XVII, 1938, 141-148.

5. Studies in the Soil Fungi of the Paddy fields of Bengal. I. Fungi of an unmanured paddy field of Chinsurah Agricultural Farm (with his research student, Mr. T. C. Roy—in the Press).

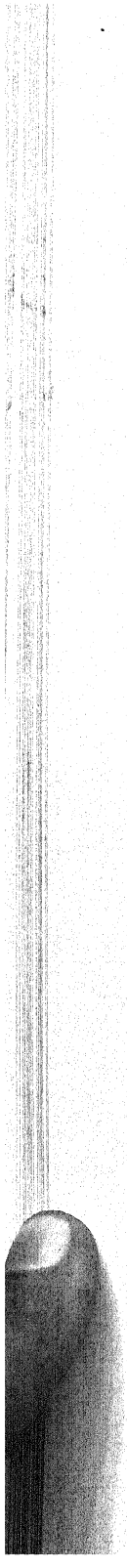
6. He was also studying rots of Indian fruits with one of his students.

7. His researches on the storage rot of oranges specially of Darjeeling and Shillong and Kalimpong varieties were of much practical value.

Dr. Ghatak had photography and string music as his hobbies. He was a good marksman too. In his private life he was of charitable disposition and he used to help several poor students of his native village and district.

A noble personality has passed away. May his soul rest in peace.

R. M. DATTA.



REVIEW

Experiments in Plant Physiology by Loomis and Shull; Mcgraw-Hill Publishing Co., Ltd., London; 1939. Pp. 213; Price 12/-.

As is mentioned in the preface, this book is a revision, partly re-written, of the first part of "Methods in Plant-physiology" by the same authors, and published by the same firm some time back. The former, and much larger book was intended for the advanced and the research student, while the present volume is excellently suited as a laboratory guide for the B.Sc. classes of Indian Universities. The experiments given herein are classified by the authors themselves under two heads—elementary and advanced. The total number of experiments given in this book is 167. It is praiseworthy that the authors have attempted to simplify the equipment and procedure for the experiments without sacrificing scientific technique and accuracy. This is an important factor in view of the fact that this small volume is intended to be used, not by the research student, but by one who has just begun to take a serious interest in plant physiology. In spite of the simple equipment that is required for most of these experiments, there is no doubt that they give quite reliable data.

Another good feature of the book is that each experiment simply sets the procedure to the student, but does not give the exact results that are to be obtained or will be obtained. The omission of the precise experimental results in this book compels every student to make his own observations and record the results. Immediately after each experiment, in place of the results, are given a few questions, which the student can answer only if he has completely recorded the results, and thought over them properly. The questions are so worded as to develop a critical outlook and independent thinking in the student. A few references to standard publications are also included. The style is throughout simple, and the statements are unambiguous. The book is divided into thirteen chapters, the first chapter being a general one on scientific method. The succeeding chapters are—the water relations of plants, Transpiration, Plant nutrients, the role of diffusion in plants, Colloidal phenomena in plants, Photosynthesis, Plant pigments, Plant foods, Respiration, Plant enzymes, Growth and movement, Growth differentiation balance, and growth correlation. A few experiments on hormone action also have been mentioned and it helps in creating in the student an interest in recent research work. There are altogether 52 illustrations but the number could have been increased with advantage. The book suits its purpose admirably, as a laboratory guide in plant physiology.

V. S. R.

The Journal of the Indian Botanical Society

(Formerly "The Journal of Indian Botany")

VOL. XVIII] JUNE, 1940 [Nos. 4–6

THE STUDY OF THE EFFECT OF A MIXTURE OF TWO PARTS OF BLUE-VIOLET RAYS AND ONE PART OF WHITE LIGHT ON THE FORMATION OF CARBOHYDRATES IN LEAVES

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(Communicated by R. H. Dastur)

Received for publication on November 15, 1939

Dastur and Solomon (1937) studied the effect of superimposing a beam of the blue-violet light on a beam of white light from an electric lamp on the formation of carbohydrates in the leaves. The ratio of the extra blue-violet light to the white light was kept 1 : 1. They found that more carbohydrates were formed in this light than in pure white light from the electric lamp.

It was therefore undertaken in the present investigation to see if by increasing the proportion of blue-violet light in the mixed light, a further increase in the formation of the carbohydrates is obtained or not. Such an experiment would ultimately lead us to determine the optimum ratio of the two lights in the mixed light for the photosynthetic process. In the following investigation the ratio of the blue-violet and the white light from the electric lamp were so mixed that the ratio between the two was two parts of blue-violet and one part of white light.

Method of Experimentation

The same method of experimentation employed by Dastur and Solomon (1937) was used here. In order to make the ratio 2 : 1, the intensity of the white light had to be lowered as it was not possible to increase the intensity of the blue-violet rays by any means.

The time of exposure and the methods of extraction and analysis of carbohydrates were the same as used by Dastur and his colleagues (1933, 35, 37) in this laboratory.

The results of the carbohydrate analyses of the leaves of *Helianthus annuus* L., *Ricinus communis* L., *Nicotiana Tabacum* L., and *Abutilon asiaticum* G. Don., exposed to ordinary white electric light and mixed light are given in Table I.

TABLE I

Total Carbohydrates of the Leaves of Plants before and after Exposure to Different Lights

Intensity of Light = 6

Experiment	Total carbohydrates of the leaves in		
	Dark	Two parts of Blue-violet and one part of white light	White electric light
	Helianthus annuus L.		
1	0·0182	0·0231	0·0319
2	0·0237	0·0390	0·0533
3	0·0217	0·0263	0·0429
4	0·0242	0·0387	0·0497
5	0·0256	0·0303	0·0446
6	0·0272	0·0332	0·0493
	P = 0·01		
	Nicotiana Tabacum L.		
1	0·0577	0·0632	0·1025
2	0·0538	0·0852	0·1224
3	0·0611	0·0685	0·1044
4	0·0558	0·0738	0·0938
5	0·0482	0·0630	0·0909
6	0·0523	0·0688	0·0996
7	0·0874	0·0693	0·0879
	P = 0·01		

TABLE I—(*Contd.*)

Experiment	Total carbohydrates of the leaves in		
	Dark	Two parts of Blue-violet and one part of white light	White electric light
	Ricinus communis L.		
1	0·0481	0·0553	0·0634
2	0·0504	0·0607	0·0712
3	0·0440	0·0560	0·0744
4	0·0457	0·0514	0·0657
5	0·0547	0·0600	0·0796
6	0·0499	0·0587	0·0682
	P = 0·01		
	Abutilon asiaticum G. Don.		
1	0·0564	0·0681	0·0912
2	0·0489	0·0641	0·1001
3	0·0660	0·0720	0·0995
4	0·0495	0·0668	0·0984
5	0·0392	0·0512	0·0844
6	0·0450	0·0617	0·0905
	P = 0·01		

The results obtained in the above investigations are statistically tested by employing Fisher's "*t*" test and it is found that the carbohydrates formed in white light were significantly higher than the carbohydrates formed in the mixed light (2 parts of blue-violet and one part of white light).

CONCLUSIONS

The formation of carbohydrates in leaves was found by Dastur and Solomon (1937) to increase in white light from an ordinary electric lamp when an equally intense beam of blue-violet rays was

superimposed on the beam of white light. The ratio of the intensities of the two beams was 1 : 1. In this investigation the intensity ratio of the two beams was altered with two parts of blue-violet rays and one part of white light and it was found that the formation of carbohydrates was depressed as compared with the unmixed white light of the same total intensity. This decrease is not probably caused by the greater proportion of the blue-violet light in the mixed light but is probably due to lowering of the intensity of red rays which are also important for the process. In order to make the ratio 2 : 1 between blue-violet and white light the intensity of the latter had to be reduced as it was not possible to increase the intensity of blue-violet beam. The decrease in the intensity of the white light caused the decrease in the red rays along with other rays of the white light which is known to be intense in the red-yellow region but poor in the blue-violet rays. The decrease in the red rays may have decreased the formation of carbohydrates. Thus the findings here and of the previous workers show that in white light from an electric lamp the formation of the carbohydrates is low and the process is limited by the poverty of the blue-violet region in that light. If a beam of blue-violet rays is superimposed on an equally intense beam of white light the rate of the process is increased, so long as the red rays do not become limiting which happened to be the case in this investigation. Unless a suitable method can be devised it is not possible to study the effect of a further increase in the intensity of the blue-violet rays on the formation of carbohydrates in the leaves.

Summary

By superimposing a beam of blue-violet light on the white light from an electric lamp in the ratio 1 : 1 Dastur and Solomon (1937) found that the formation of carbohydrates in leaves was increased as compared with the unmixed white light of equal intensity. It was, therefore, undertaken to study the effect on the process of the mixed light in proportion of two of blue-violet and one of white light. Such a mixture of light could only be obtained by decreasing the intensity of the white light as it was not possible to increase the intensity of the blue-violet rays.

The results of the carbohydrate analysis showed that by making the ratio of blue-violet light to white light 2 : 1 in the mixed light, there was a decrease in the formation of carbohydrates in the leaves, as compared with the carbohydrates formed in the unmixed white light of equal intensity. This was probably due to the relative decrease in the intensity of the red region, as by lowering the intensity of the white light in the mixed light, a decrease in the intensity of the red rays occurred which acted adversely on the process.

Acknowledgement

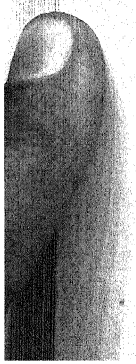
The authors wish to acknowledge their indebtedness to Prof. R. H. Dastur, M.Sc., F.L.S., for his criticism and help during the course of this investigation.

BIBLIOGRAPHY

1. Dastur, R. H., and Mehta, R. J. (1935) "The Study of the Effect of Blue-violet Rays on Photosynthesis," *Ann. Bot.*, **49**, 808–22.

2. ———, and Samant, K. M. (1933) "A method for the determination of Carbohydrates in Leaves," *Ind. Jour. Agric. Sci.*, **3**, Part 3, 460–77.

3. ———, and Solomon, S. S. (1937) "Study of the Effect of Blue-violet Rays on the Formation of Carbohydrates in Leaves," *Ann. Bot.*, N.S., **1**, 147–52.



STUDIES IN THE MALPIGHIACEÆ

I. Embryo-sac Development and Embryogeny in the Genera *Hiptage, Banisteria* and *Stigmatophyllum*

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INTRODUCTION

VERY few investigations have appeared on the embryology of the family Malpighiaceæ. Schürhoff (1924) gave a brief account of the development of the female gametophyte in *Malpighia coccifera* L., *M. urens* L., and *Bunchosia nitida* Jacq., and reported in them a sixteen-nucleate embryo-sac developing according to the "*Penœa*-form" of the *Peperomia*-type. There are four peripheral groups composed of three cells each looking like egg-apparatuses and four free polar nuclei fusing in the centre. Stenar (1937) has confirmed this in *Malpighia urens* and Narasimhachar (1938) in *Malpighia punicifolia*. In *Galphimia gracilis* (Stenar, 1937) and *Malpighia glauca* (Subba Rao, 1939), however, the embryo-sac is eight-nucleate and arises from the lower dyad cell (*Allium*-type).

Braun (1860) recorded polyembryony in *Banisteria* and *Stigmatophyllum* and Ritzerow (1908) in three species of *Aspicarpa*. The latter states that there is no fertilisation and the embryos are situated away from the micropyle.

MATERIAL AND METHODS

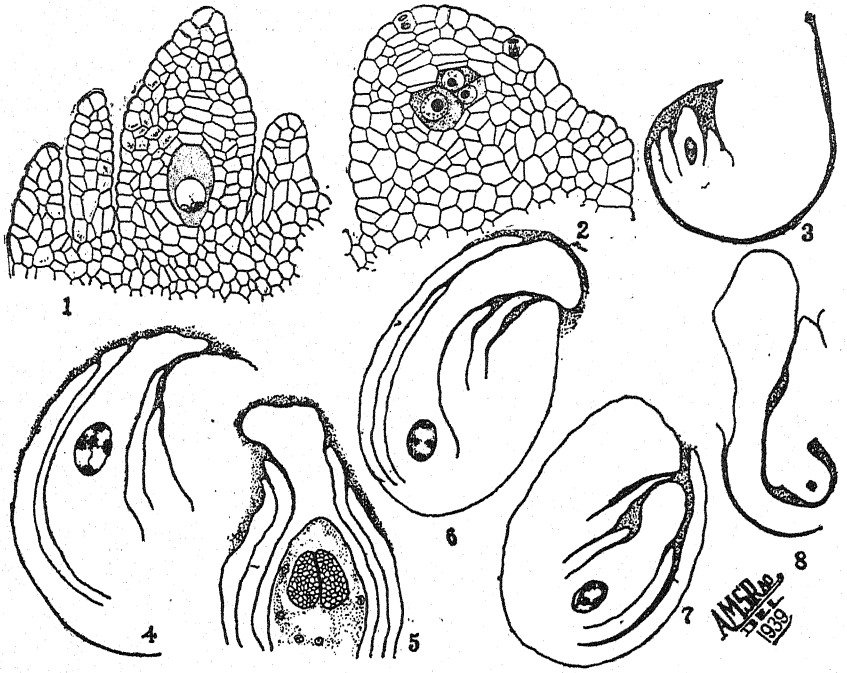
Three species were investigated, each belonging to a different genus. The material of *Hiptage madablota* Gaertn., a common climber in the tropics, was collected from the Botanical Gardens, Central College, Bangalore. *Banisteria laurifolia* L., and *Stigmatophyllum aristatum* L., cultivated as ornamental shrubs, were collected from the Lal-Bagh Horticultural Gardens, Bangalore. Unfortunately the last two do not form any seeds here and therefore the embryonal development could not be studied in these plants.

Bouin's fluid was used for fixation. The ovary wall was removed as far as possible not only to facilitate penetration but also to avoid difficulties in sectioning. For stages in the development of the embryo, it was found necessary to fix the ovules separately.

Sections were cut at varying thicknesses from 10–16 microns and stained in Haidenhain's iron-alum hæmatoxylin.

THE OVARY AND OVULES

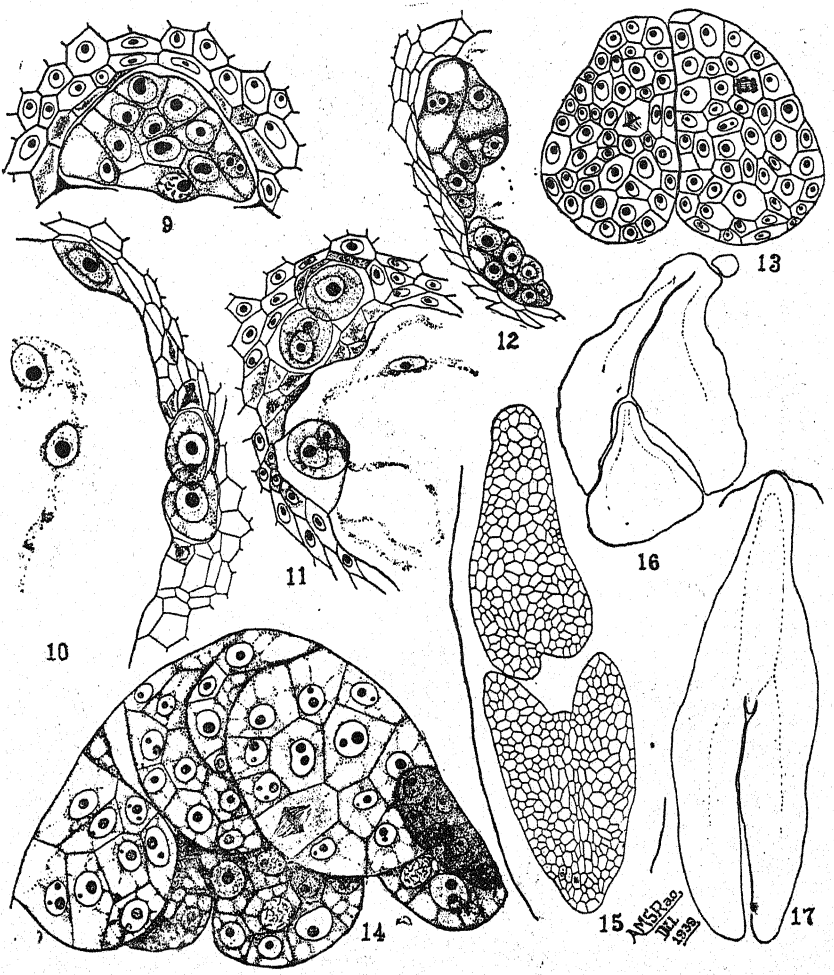
In all these plants the ovary is profusely covered with hairs, and in *Hiptage Madablota* it is obliquely placed in the floral cup.



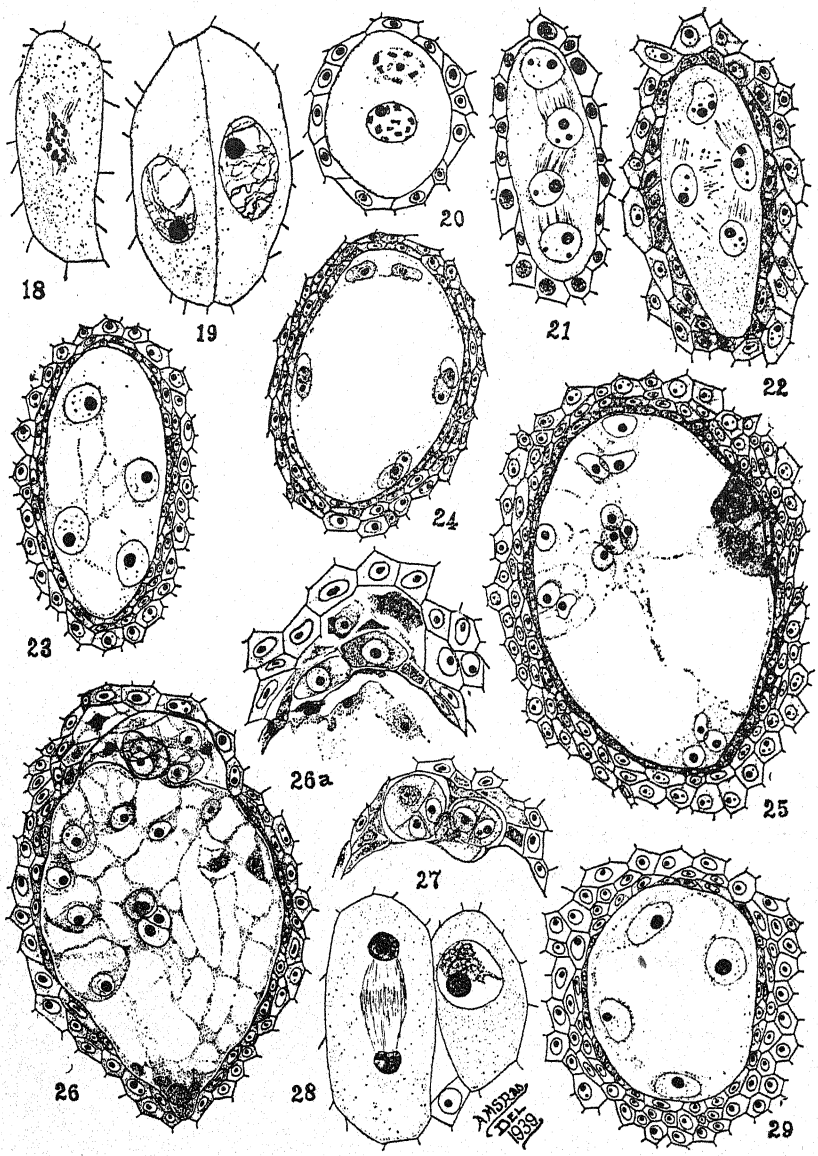
Figs. 1, 3, 4 and 5—*Hiptage Madablota*; Figs. 2, 7 and 8—*Banisteria laurifolia* and Fig. 6—*Stigmatophyllum aristatum*. Fig. 1. L. S. of an young ovule at the megaspore-mother cell stage to show the many-layered parietal tissue (× 252). Fig. 2. Primordium of the ovule showing 3 archesporial cells and laying down of the integument (× 405). Figs. 3–5. Sections of the ovule to show the development of the two integuments and the long nucellar-beak [× 72 (all)]. Fig. 6. Section of an ovule showing an 8-nucleate embryo sac, an abnormally big nucellar-beak and shorter inner integument (× 72). Figs. 7–8. Stages in the development of the nucellar-beak and integuments (× 108).

It is trilocular with one semianatropous ovule in each locule. The styles are trifid (except in *Hiptage*, where there is only one) and in *Stigmatophyllum* the stigmas are large and leafy.

The young nucellus which arises from the top of the axile placenta at first points towards the base of the ovary (Fig. 7), unlike in *Plumbago capensis* (Haupt, 1934) where it is directed upwards. Just at the megaspore-mother cell stage it bends near the middle of the long funiculus by a rapid growth on one side and faces the placenta. Further bending makes it point upwards (Figs. 3, 4, 6 and 8). Thus, the funiculus forms a loop by the time the nucellus contains a mature embryo-sac. The curvature of the ovule is more pronounced in the case of *Plumbago capensis* since the ovule in the beginning points upwards, later it bends in the opposite direction, becomes inverted and further curvature of the ovule continues until it has its micropyle pointing upwards.



Figs. 9–17—*Hiptage Madablota*. Fig. 9. An old embryo projecting into the embryo-sac cavity whose wall is ruptured (× 567). Fig. 10. Part of an embryo-sac showing one enlarged nucellar cell at the micropylar end and 2 on the right side of it (× 567). Fig. 11. Same showing enlarged nucelar cells, 2 at the micropylar end and one slightly towards a side (×567). Fig. 12. One embryo near the micropylar end and the other towards a side ; both of them are many celled (× 405). Fig. 13. Two embryos, older stage, situated at the micropylar end (× 252). Fig. 14. Micropylar portion of embryo-sac showing 8 embryos of which the one to the right is degenerating (× 567). Fig. 15. Micropylar portion of another embryo-sac with two advanced embryos. In both of them cotyledons are distinct though disposed in opposite directions (× 72). Fig. 16. Two big embryos, one of which is inserted between the cotyledons of the other (×13·5). Fig. 17. A mature embryo with cotyledons and stem-tip clearly differentiated (× 36).



Figs. 18–27—*Hiptage Madablota* and Figs. 28–29—*Banisteria laurifolia*. Fig. 18. Megaspore-mother cell in division; note multipolar spindle (× 567). Fig. 19. Two megaspore-mother cells in the same ovule (× 567). Fig. 20. Two-nucleate stage after completion of heterotypic division (× 567). Figs. 21–23. Four-nucleate stage [× 567 (all)]. Fig. 24. Eight-nucleate stage (× 405). Fig. 25. Mature embryo-sac showing four groups of three cells each and four polars. The triad to the right has begun to degenerate (× 405). Fig. 26. Embryo-sac showing the initiation of

The integuments originate quite early in *Banisteria laurifolia* and *Stigmatophyllum aristatum*. Their development conforms to the type described for *Malpighia urens* (Figs. 6–8). In *Hiptage madablota* the integuments originate normally, but unlike *M. urens* the inner always projects beyond the outer (Figs. 3–5). In *Malpighia urens* (Stenar, 1937) the inner integument is very small and the outer is very long and reaches the top of the nucellus during the megaspore-mother cell stage of the ovule. Later the outer grows fast and forms an arch over the nucellus. At the four-nucleate stage of the embryo-sac the nucellus protrudes out of the big ring-like aperture formed by the inner integument and enlarges.

Due to the activity of the parietal cells the nucellus enlarges and soon projects beyond the inner integument (Figs. 1–3). In *Stigmatophyllum* it is especially prominent and projects out of the micropyle (Fig. 6). It persists for a long time, and in *Hiptage madablota* it can be seen even during the later stages of the embryonal development (Fig. 5). Thus, irrespective of the inner integument being shorter or longer, the nucellus always projects beyond it in these plants.

The Archesporium

The archesporial cells are hypodermal in origin and cut off parietal cells in the normal way. The megaspore mother cell becomes deeply embedded by the further divisions of the parietal cells and the nucellar epidermis. In later stages the wall tissue and epidermal tissue grade imperceptibly into one another.

The presence of a multiple archesporium is of a common occurrence in these plants (see also Narasimhachar, 1938, on *Malpighia punicifolia*) although Schürhoff (1924) makes no mention of it (Figs. 2 and 34). Only one of the archesporial cells, however, usually develops as a megaspore-mother cell. In only one instance two megaspore-mother cells were seen in *Hiptage Madablota* and *Banisteria laurifolia* (Figs. 19 and 28). In the latter one of the mother cells was in the heterotypic telophase while the other was still in the early prophase. For some time both may continue to develop, but usually one gets far ahead of the other, which then becomes suppressed. Rarely two embryo-sacs may develop in the same ovule (Fig. 33 of *Banisteria laurifolia*). Such a condition might have arisen from two megaspore-mother cells placed one above the other.

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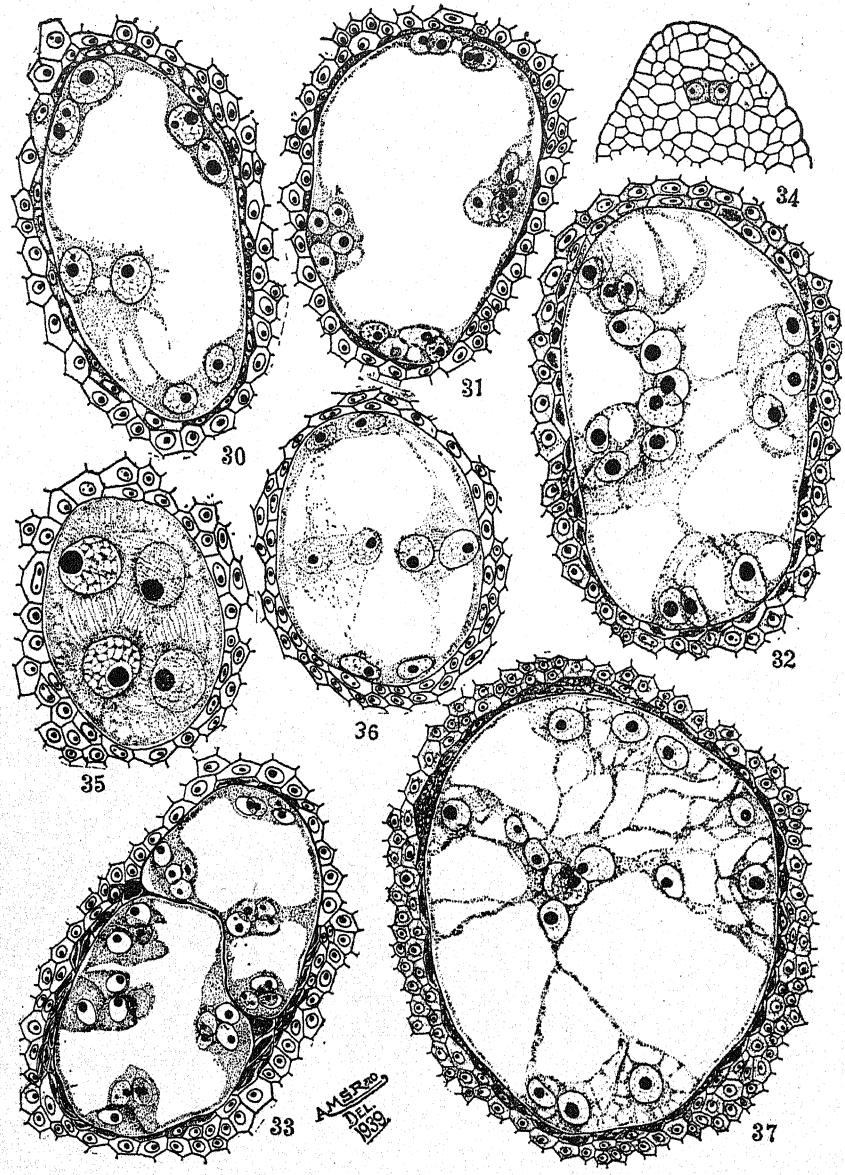
four nucellar embryos at the micropylar end. The polars have not yet fused and the antipodal triad has degenerated (× 405). Fig. 26 (*a*). Micropylar portion of an embryo sac showing two enlarged nucellar cells. A few of the adjacent cells have degenerated to make room for the former (× 567). Fig. 27. Same showing 3 nucellar embryos, which have begun to force their way into the embryo-sac cavity (× 360). Fig. 28. Two megaspore-mother cells. One has completed the heterotypic division while the other is still in the prophase (× 810). Fig. 29. Four-nucleate stage (× 567).



Figs. 30–33—*Banisteria laurifolia* and F gs. 34–37—*Stigmatophyllum aristatum*. Figs. 30–31. Eight- and sixteen-nucleate stages respectively. In the latter the polar nuclei have not yet moved to the centre. Fig. 30. (× 810). Fig. 31 (× 567). Fig. 32. Mature embryo-sac showing four groups of three nuclei each and four free nuclei meeting in the centre (× 567). Fig. 33. Two sixteen-nuclete embryo-sacs in the ovule (× 567). Fig. 34. An young ovule showing two archesporial cells after cutting off two parietal cells (× 405). Figs. 35–37. Four-, eight- and sixteen-nucleate stages respectively. Fig. 35 (× 810). Figs. 35 and 37 (× 405).

Formation of the Megaspore Nuclei

The megaspore-mother cells have very big nuclei. Their cytoplasm is fibrillar in the region adjacent to the nucleus, while numerous minute vacuoles are seen towards the periphery (Fig. 19). The heterotypic division is not followed by wall formation (Figs. 20 and 28) and the daughter nuclei divide again. The two spindles are commonly placed obliquely to each other. The four nuclei formed as a result of this division are arranged in a cross-wise manner and due to the formation of the secondary spindle fibre all the four nuclei are seen attached to one another for some time (Figs. 21, 22 and 35).

Development and Organisation of Mature Embryo-Sac

With the enlargement of the cell, vacuoles begin to make their appearance in the embryo-sac and the adjoining nucellar cells are partly flattened and crushed (Figs. 23 and 29). Each of the four nuclei divide twice, and consequently, there arise four groups of four nuclei each. One nucleus from each group migrates to the centre and the four fuse to form a secondary nucleus. The remaining four groups of three each remain in their original places, but develop walls around them. The three nuclei of the egg-apparatus are not clearly distinguishable into synergids and egg and all of them degenerate later (Figs. 24, 25, 30–32, 36 and 37). In Fig. 25 three cells of the egg-apparatus on the right side have already degenerated. In *Banisteria laurifolia* and *Stigmatophyllum aristatum* the sacs enlarge very much and finally the whole embryo-sac degenerates. The organisation of the mature embryo-sac in all the three genera was generally found to be quite uniform unlike the condition in *Peperomia hispidula* (Johnson, 1914) and *Acalypha indica* (Maheshwari and Johri, 1940).

Absence of Fertilisation

Ritzerow (1908) concluded the absence of fertilisation in the genus *Aspicarpa* on the following grounds :—

i. the absence of any pollen tubes or their remains in embryo-sacs having young embroys ;

ii. the situation of all the embryos away from the micropyle ;

iii. the lack of normal development of the pollen.

Fertilisation was not observed in any of the three species investigated here. The following facts disprove its occurrence :—

i. the poor organisation of the embryo-sac and its early degeneration ;

ii. degeneration of pollen grains and the emptiness of the anthers caused by the attacks of insect larvæ—more specially in *Hiptage Madablota* ;

iii. the lack of normal development of the pollen ;

iv. failure of germination of the few pollen grains that may still remain. A considerable time was spent in trying to germinate the pollen of *Hiptage madablota*, but the results are negative.

Endosperm Formation

Though fertilisation is absent, the secondary nucleus divides in *Hiptage Madablota* to form a number of free endosperm nuclei. A few of these migrate to the antipodal end, enlarge and take a dark stain. Owing to their further activity the chalazal end of the embryo-sac becomes very large and curved and probably exercises a haustorial function as in *Euphorbia procera* and *E. virgata* (Modilewski, 1909, 1910). No embryo or endosperm formation was noticed in *Banisteria laurifolia* and *Stigmatophyllum aristatum*.

Nucellar Embryos

In spite of lack of fertilisation embryos are still produced in *Hiptage Madablota*. These are all nucellar and their formation commences even before the fusion of the polars is completed (Fig. 26). In one case two- or three-celled embryos and in another still larger one, were observed encroaching on the embryo-sac (Figs. 9 and 27). These enlarged nucellar cells divide either *in situ*, in which case some of the adjacent nucellar cells degenerate and make room for the growth of the former (Fig. 26*a*), or if they happen to be very near the embryo-sac they enter the cavity, divide several times and form a mass of cells (Figs. 9, 12 and 14), which later on takes the usual form of a dicotyledonous embryo with a short and massive suspensor-like portion (Fig. 15).

Leeuwenhock, Braun (1859), Tiwary (1926) and others have described many cases of polyembryony. Chakravarthy (1935, 1936) in *Murraya Koenigii*, *M. exotica* and *Aegle marmelos* and Juliano and Cuevas (1932) in "*Pico*" varieties of mangoes report polyembryony where the normal embryo is mixed with nucellar embryos. Juliano (1934) has published an account of polyembryony in "*Strawberry*" mangoes, where the normal embryo has a shrunken appearance from the beginning and finally degenerates making room for the developing nucellar embryos. Commonly the development of the nucellar embryos commences after fertilisation and the normal embryo is thus present along with the others at least for some time. As mentioned before, in *Hiptage Madablota* an egg-embryo does not arise at all on account of the degeneration of all the four groups of egg-apparatuses.

Most of the nucellar embryos are micropylar. In a few cases only, they occupied a lateral position. Their mode of development is, however, the same.

In the Malpighiaceæ, all the genera hitherto studied,—*Hiptage*, *Aspicarpa*, *Banisteria*, *Heteropteris* and *Stigmatophyllum*,—show nucellar polyembryony. The only exception is *Malpighia punicifolia* in which Narasimhachar (1938) records a single embryo

(presumably formed from the fertilised egg?) at the micropylar end of the embryo-sac.

Seeds are said to develop in only one locule of the ovary in *Malpighia urens*. In *Hiptage Madablota* they develop either in two locules, which is very common, or in one or all the three locules. Most of the mature seeds contain only one embryo but a few have two or even three. All have two cotyledons and a stem-tip (Fig. 17). Usually one seedling develops from a seed. Occasionally, however, more than one seedling is seen to emerge from the seed.

Discussion

The old view sponsored by some botanists, that the many nucleate embryo-sacs of *Peperomia*, *Penæa*, *Pandanus*, etc., represent a transition from the type of embryo-sac in *Gnetum* to that seen at present among the majority of the angiosperms has lost favour in recent years. Their occurrence is too scattered (Piperaceæ, Epuhorbiaceæ, Penæaceæ, Gunneraceæ, Malpighiaceæ, Umbelliferæ, Compositæ, Liliaceæ and Pandanaceæ) to justify such a conclusion and the writer is in agreement with the opinion expressed by Miss Stephens, " that the peculiarities of the embryo-sac (of the Penæaceæ) may. . . . be best explained by regarding it as a specialised type, in the development of which all the four megaspores have become included, the germination of each ceasing at the four-nucleate stage." Schnarf (1936) who is the leading authority on the subject also states that the monosporic eight-nucleate

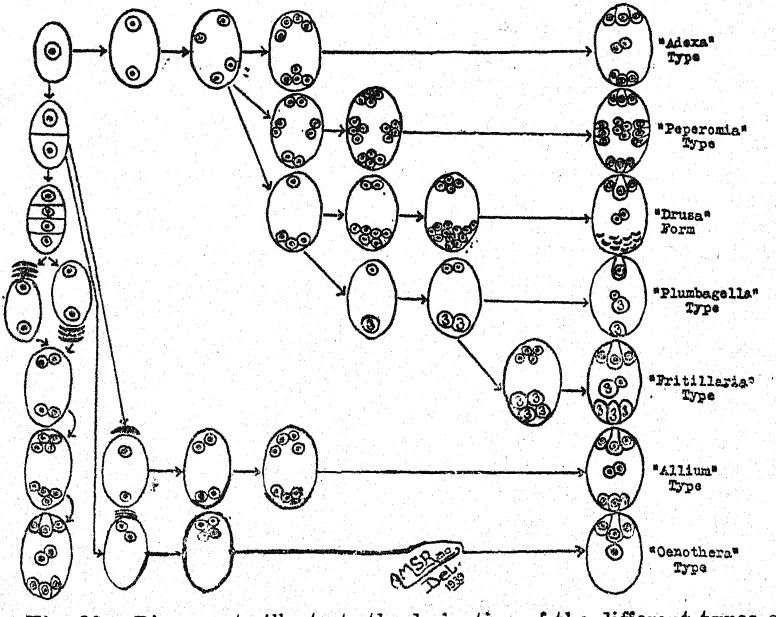


Fig. 38. Diagram to illustrate the derivation of the different types of embryo-sacs from the monosporic 8-nucleate one.

embryo-sac is the fundamental type in angiosperms and that all the others are modifications of this, derived by a decrease in the number of divisions taking place between the megaspore mother cell and the egg or by an increase in the number of megaspores taking part in the formation of the sac.

The methods by which the other types of embryo-sacs may have been derived from the normal (monosporic eight-nucleate) are expressed in the above chart.

The normal eight-nucleate embryo-sacs, if they are to be considered or accepted as the fundamental type in angiosperms—since they are the most predominant type—have given rise to the " *Allium*-type ", wherein, the two megaspores have begun to function in place of the one, and they in turn to the " *Adoxa*-type ", where all the four function and from them the eight- and sixteen-nucleate embryo-sacs of *Peperomias*, *Piper ?*, *Fritillaria* and *Malpighia* have resulted. Thus one finds, when comparing these different types of embryo-sacs, that the four- and sixteen-nucleate embryo sacs to be either reduced or advanced types derived from the normal type.

Summary

1. The following plants were investigated : *Hiptage Madablota*, Gaertn., *Banisteria laurifolia*, L., and *Stigmatophyllum aristatum*, L.

2. There is a multiple archesporium in all the three genera. The megaspore mother cell becomes deeply embedded on account of the presence of a large number of parietal cells which give rise to a massive nucellar tissue projecting beyond the inner integument.

3. The nucleus of the megaspore mother cell undergoes two divisions, the first being reductional, and four free nuclei are formed. They are arranged cross-wise. A linear tetrad of mesgaspores is absent in all the three genera.

4. Each megaspore nucleus divides twice to form a quartet ; one nucleus from each of the group now migrates to the centre of the sac to form the secondary nucleus. The organisation into the egg and the synergids is not well-marked and all the four triads degenerate.

5. Fertilisation is absent in all the three plants.

6. Some of the nucellar cells in *Hiptage Madablota* adjacent to the micropylar part of the embryo-sac divide even before the fusion of the polars is complete. These give rise to nucellar embriyos.

7. *Hiptage Madablota* shows polyembryony (the other two species *Stigmatophyllum aristatum* and *Banisteria laurifolia* do not form any seeds at Bangalore), the embryos arising mostly from the nucellar cells of the micropylar end of the embryo-sac and rarely from the sides.

8. The relationships of the different types of embryo-sacs are discussed.

In conclusion, I take this opportunity of expressing my indebtedness to Dr. M. A. Sampathkumaran, M.A., Ph.D., S.M. (Chicago),

University Professor of Botany, for encouragement and constant guidance throughout the course of the present investigations. Finally, it is my pleasant duty to express my sense of gratitude to Dr. P. Maheshwari, D.Sc., University of Dacca, for his able and helpful criticism.

LITERATURE CITED

*Braun, A. (1860, 1859) .. " Über Polyembryonie und Keimung von *Cœlebogyne*. Ein Nachtrag zu der Abhandlung über Parthenogenesis der Pflanzen," *Abh. Akad. Ber. Phys. Kl.*, 107–263.

Campbell, D. H. (1899) .. " A Peculiar Embryo-sac in *Peperomia pellucida*," *Ann. Bot.*, **13**, 626.

Chakravarthy, R. S. (1936).. " Nucellar polyembryony in the Rutaceæ," *Curr. Sci.*, **5**, 202–03.

Coulter, J. M., and Chamberlain, C. J. (1903) *Morphology of Angiosperms*, New York.

Haupt, A. W. (1934) .. " Ovule and Embryo-sac of *Plumbago capensis*," *Bot. Gaz.*, **95**, 649–59.

Ishikawa, M. R. (1918) .. " Studies in the embryo-sac and fertilisation in *Oenothera*," *Ann. Bot.*, **32**, 279–317.

Johnson, D. S. (1902) .. " On the development of certain Piperaceæ," *Bott. Gaz.*, **34**, 321–40.

Johnson, D. S. (1914) .. " Studies in the development of Piperceæ II. The structure and seed development of *Peperomia hispidula*," *Amer. Jour. Bot.*, **1**, 329–339, Taf. 36–38, 41–43.

Juliano, J. B., and Cuevas (1932) " Philippine Agri." (*Review in Jour. Ind. Bot. Soc.*, **15**, 1936).

———— (1934) .. " Origin of embryos in '*Strawberry*' Mango," *Philippine Jour. Sci.*, **54**, 553–61.

Maheshwari, P. (1937) .. " A critical review of the types of embryo-sacs in Angiosperms," *New Phyt.*, **36**, 359–417.

———— (1939) .. " Are the Angiosperms polyphyletic ?" (to appear in *Chronica Botanica*).

———, and Johri, B. M. .. " The embryo-sac of *Acalypha indica* L." (in the press).

*Modilewsky, J. (1909) .. " Zür Embryobildung von *Euphorbia procera*," *Ber. deutsch. Bot. Gesell.*, **27**, 21–26.

*———— (1910) .. " Weitere Beiträge zur embryobildung einiger Euphorbiaceen," *Ber. deutsch. Bot. Gesell.*, **28**, 413–18.

Narasimhachar, S. G. (1938) " Microsporogenesis and female gametophyte in *Malpighia punicifolia* L.," *Curr. Sci.*, **6**, 507–09.

*Ritzerow, H. (1908) .. " Über Bau und Befruchtung kleistogamer Blüten," *Flora*, **98**, 163–212.

*(Denotes that the origianl papers were not available for reference. Extracts from Schnarf's *Embryologie der Angiospermen*, Berlin, 1929.)

Schnarf, K. (1929) .. *Embryologie der Angiospermen*, Berlin.

———— (1931) .. *Vergleichende Embryologie der Angiospermen*, Berlin.

———— (1936) .. " Contemporary understanding of embryo-sac development among angiosperms," *Bot. Rev.*, **2**, 565–85.

Schürhoff, P. N. (1926) .. " Die Zytologie der Blütenpflanzen," Stuttgart.

Stenar, H. (1934) .. " Embryologische und zytologische Beobachtungen uber *Majanthemum bifolium* und *Smilacina stellata*," *Arkiv. f. Bot.*, **26**, 1–20.

———— (1937) .. " Zur Embryosackentwicklung einiger Malpighiazeen," *Bot. Notiser*, 110–18.

Subba Rao, A. M. (1937) .. " A note on the development of the female gametophyte of some Malpighiaceæ and polyembryony in *Hiptage Madablota* ," *Curr. Sci.*, **6**, 280–82.

———— (1939) .. " The ovule and embryo-sac development of some Malpighiaceæ," *Curr. Sci.*, **8**, 79–81.

Tiwary, N. K. (1926) .. " On the occurrence of polyembryony in the genus *Eugenia*," *Jour. Ind. Bot. Soc.*, **6**, 125–36.

A CONTRIBUTION TO THE LIFE-HISTORY OF *BERGIA AMMANIOIDES* ROXB.

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INTRODUCTION

THE Elatinaceæ is a small family of the Parietales consisting of herbs and undershrubs. It has two genera, namely, *Elatine* and *Bergia*, comprising about thirty-five species (Rendle, 1925). Though small in the number of genera and species, the family is very widely distributed, being present in the tropical and temperate regions of both the hemispheres. Both the genera are represented in India (Hooker, 1875). A study of the previous literature on the embryology of this family shows that only the genus *Elatine* has been studied so far. The other genus *Bergia* has been altogether neglected. For this reason it was considered appropriate to study the life-history of *Bergia ammanioides* Roxb., an annual herb common at Benares.

PREVIOUS WORK

The most recent work on the family is that of Frisendahl (1927). Besides this, Schnarf (1931) mentions two other papers dealing with the embryology of this family, one by Jönsson (1879) and the other by Müller (1847), but they are of mere historical interest. Jönsson has described the embryo-sac of *Elatine hydropiper*, indicating that the antipodals degenerate in the mature embryo-sac. From the researches of Frisendahl (1927) on the same genus, we find that the ovule has two integuments and the nucellus is quite massive. The archesporium consists of many cells, but generally only one develops further, while others form part of the nucellus. The development of the embryo-sac is of the normal type, but often two or more embryo-sacs develop simultaneously in an ovule. Sometimes these embryo-sacs fuse and thus multi-nucleate embryo-sacs arise. The antipodals are generally three in number. At times the antipodals are represented by three naked nuclei or may be altogether absent. The mature embryo-sac is then only four-nucleate. The tapetum of the anther is of the secretory type and does not form any periplasmodium. The pollen-mother cells divide simultaneously to form four pollen grains. The latter are shed either at the 2- or 3-nucleate stage. The endosperm is nuclear in the beginning but afterwards it becomes cellular. Wall formation in the endosperm starts in the chalazal region and extends towards the micropylar end.

So far no attempt has been made to describe the development of the embryo in this family. The present communication aims at describing this phase of the life-history also.

Material and Methods

The material for the present investigation was collected from the banks of a pond in front of the Engineering College of the Benares Hindu University. Nawaschin's fluid was used for fixing. After keeping the material for 24 hours in the fluid it was directly transferred to 70 per cent. alcohol. It was then embedded in paraffin according to the customary methods. Sections were cut 7–10 μ thick. Heidenhain's Iron-alum Hæmatoxylin was mostly used as stain and saturated solution of picric acid served quite satisfactorily for destaining the slides. To study the pollen grains Methyl-green glycerine-jelly mounts were also used.

Microsporogenesis

The primary archesporium in an anther-lobe consists of one to three, mostly two, rows of hypodermal cells (Fig. 1). In each row there are three to five cells. All these cells cut off primary wall cells towards the outside (Fig. 2). The primary parietal layer divides periclinally into two layers (Fig. 2). Both these layers divide once again periclinally. Generally the layer adjacent to the microspore mother cells divides a little earlier than the other (Fig. 3). Due to these repeated divisions of the primary wall-layer the parietal tissue consists of four layers of cells (Figs. 3 and 4). Out of these four parietal layers the two middle layers are crushed in the course of development.

The hypodermal one develops into the fibrous endothecium. The thickening bands in the cells are formed during the maturation of the pollen grains. The innermost parietal layer forms the tapetum (Fig. 4). As in the angiosperms in general, the cells of the tapetum have one nucleus in the beginning, but during the meiotic divisions in the pollen-mother cells they become bi-nucleate. They persist till a late stage of anther development and degenerate only after the pollen grains become bi-nucleate, but once they begin to do so, they disappear rather quickly. Before degeneration the tapetal cells become prominently vacuolate. In function the tapetum is of the secretory type and the tapetal cells do not form any periplasmodium.

An interesting feature about the anther wall is the presence of tannin grains in the cells of the epidermis. The deposition of these grains begins at about the time when the primary parietal layer is cut off from the archesporium (Fig. 2). As the development of the anther progresses these grains continue to accumulate further. Many of them fuse together and thus larger grains are formed. Ultimately they completely fill all the epidermal cells of the anther (Figs. 3 and 4). They are present in the maximum quantity during the formation of the pollen grains, but at the time of anther dehiscence they decrease in amount. Similar grains are also deposited, though not so regularly, in the filaments of stamens, petals, sepals, and some parts of the gynæcium.

The primary sporogenous cells directly form the pollen-mother cells. During the two meiotic divisions and for a short time

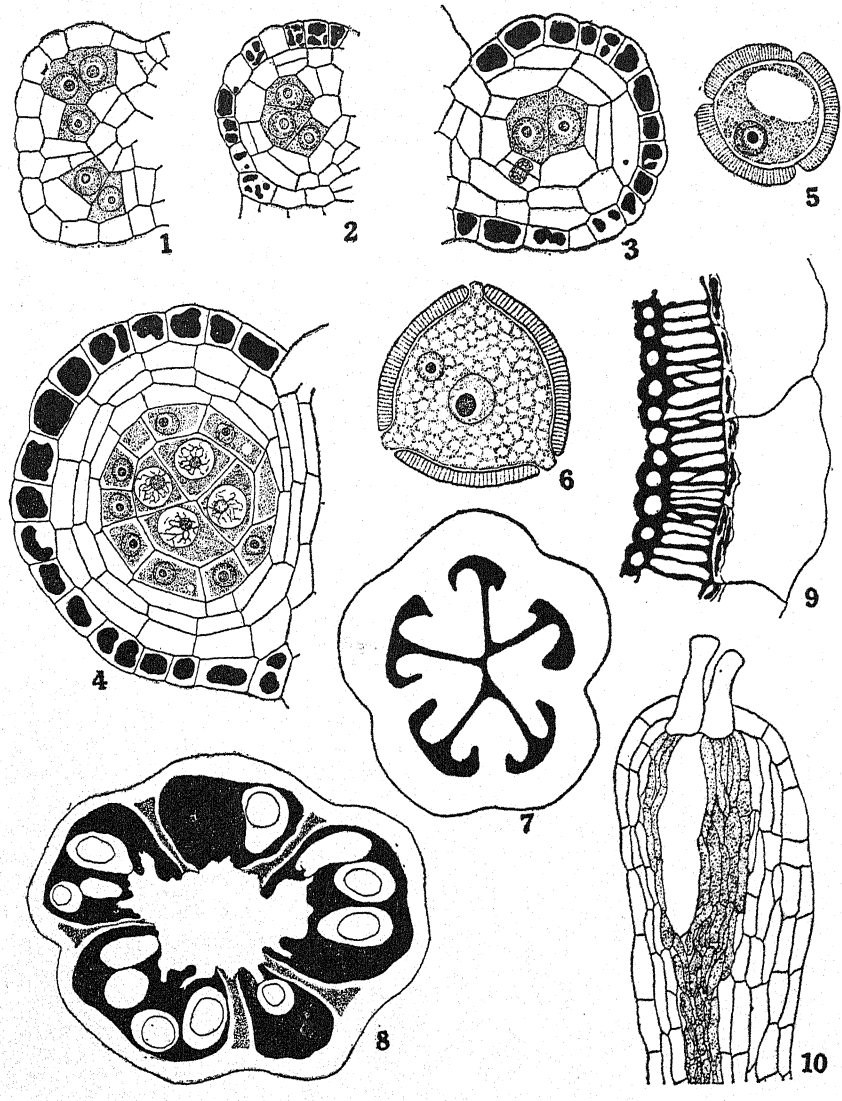
afterwards the pollen-mother cells and their products remain enclosed in a sheath of mucilage. The latter becomes quite clear in Methyl-green glycerine-jelly mount. After cytokinesis, which takes place by furrowing, four functional pollen grains are formed in each pollen-mother cell. Their general arrangement is tetrahedral, but many times they are also found arranged in an isobilateral manner. The young pollen grain is densely filled with cytoplasm, but as it increases in size, one end of it becomes vacuolate, while the nucleus along with some cytoplasm is pushed to the other (Fig. 5). The nucleus divides at the periphery and an ephemeral lenticular generative cell is organized. The wall separating the generative cell from the tube cell soon disorganizes and the generative nucleus lies free in the cytoplasm of the pollen grain. By this time the pollen grain becomes uniformly vacuolate (Fig. 6).

In the beginning the pollen grain as seen in sections is circular in outline (Fig. 5), but at the time of shedding it becomes oblate and its outline becomes bluntly triangular (Fig. 6). Generally, the pollen grain has three germinal furrows. They occupy the vertices of the triangular pollen grain and are thus equidistantly spaced. Occasionally pollen grains with two germinal furrows are also observed. A change takes place in the shape and size of the furrows as the pollen grain develops. In the young condition they are long and tapering, while in the mature pollen grain they are more blunt and not so much tapering. Each pollen grain measures 20–25 μ in diameter. The exine in surface view appears finely granular. This is due to the presence of deep staining portions, which in section appear as radially elongated bands in the exine. The intine is a delicate membrane, which in the mature pollen grains slightly protrudes out of the germ-furrows (Fig. 6).

The Structure of the Ovary and Ovule

The gynæcium is multicarpellary, the carpels varying from four to five in number. It develops from the tip of the floral axis after the latter has formed all other parts. The primordia of the carpels develop simultaneously as a cup-like outgrowth, which, as it closes at the distal end, breaks up into separate styles and stigmas. The structure of the styles is worth noting. These may be solid throughout or may be hollow in the upper part and solid below (Fig. 10). This is due to the fact that the epidermal outgrowths which form the transmitting tissue of the style meet in the centre in the lower region, while in the upper part just below the stigma these epidermal outgrowths do not meet in the centre and the transmitting tissue in this part only lines the canal.

The structure of the ovary wall may be taken up now. Generally it is four layers thick, and to begin with consists of parenchymatous cells. As the development proceeds a change takes place in the inner epidermis and hypodermis of the ovary wall. The cells of these two layers become prominently thick-walled. Further the cells of the hypodermal layer elongate radially, while those of the



Figs. 1–10.—*Bergia ammanioides.* Figs. 1-4. Transverse sections of anther-lobes at various stages of development showing the differentiation of the sporogenous and parietal layers. Figs. 5–6. 1- and 2-nucleate pollen grains. Figs. 7-8. transverse sections of two gynæcia, one young and the second old. Fig. 9. A part of the ovary wall in transverse section. Fig. 10. Upper part of the style as seen in longitudinal section. Figs. 1–4 and 9 (× 760). Figs. 5–6 (× 1280). Fig. 7 (× 160). Fig. 8 (× 80). Fig. 10 (× 250).

inner epidermis elongate, at right angles to the latter (Fig. 9). The two outer layers remain parenchymatous, but the cells of the outer

epidermis undergo a great increase in size, though even from the beginning these cells are bigger than other cells of the ovary wall (Fig. 9).

When the ovary wall is developing, four to five septa begin to develop from its inner side (Fig. 7). They meet in the centre to divide the ovary into four to five loculi (Fig. 8). Before these septa meet in the centre, the ovules begin to develop as minute papillæ on either side of the septa (Fig. 7). As the papillæ continue to develop, the primordia of the integuments make their appearance and that of the inner integument develops first (Fig. 15). By this time the archesporium differentiates. At about the megaspore-mother cell stage the ovule bends over the raphe (Fig. 11) and finally becomes anatropous (Figs. 12 and 13).

The nucellus is fairly massive to begin with. Its epidermis does not divide to form any epidermal cap, though cap formation is not unusual in the Parietales. Mauritzon (1936) has reported cap formation in many plants from this order, *e.g.*, *Bixa orellana*, *Hybanthus calycinus*, *Datisca cannabina*, etc. Up to the 8-nucleate stage of the embryo-sac the bulk of the nucellus is present in the chalazal part of the ovule, while the micropylar part is occupied by the embryo-sac surrounded by three to four layers of the nucellus (Fig. 12). The cells of the nucellus are richer in protoplasmic contents and take a deeper stain than the cells of the integuments. After the 8-nucleate embryo-sac stage the chalazal part of the nucellus is also quickly crushed by the developing embryo-sac, and before the first division of the egg the nucellus is reduced mostly to two layers of cells (Fig. 13). Of these two layers, the cells of the inner layer increase in size (Fig. 13), but they are not so rich in protoplasm as the cells of the anther tapetum. This layer begins to show signs of degeneration at about the octant stage of the embryo and disappears completely at the stage shown by Fig. 45. The outermost layer of the nucellus persists even in the mature seed. Small grains begin to appear in its cells about the time of fertilization (Fig. 13) and these continue to accumulate till the cells become completely filled up with them (Figs. 14 and 46).

Each ovule has two integuments and a short funicle. Both the integuments take part in the formation of the micropyle (Figs. 12 and 13), as in many other members of the Parietales (Mauritzon, 1936). Over the tip of the nucellus the integuments close very tightly, so much so that the micropylar canal is not very distinct. In the beginning each integument consists of two layers of cells, but in the mature seed, the inner layer of both the integuments is destroyed. Only the outer layer of each integument persists to form the testa. The cells of these layers enlarge in size. The change is more pronounced in the cells of the inner integument at the micropylar end (Fig. 13). The cells of this layer become very much enlarged and thick-walled in the mature seed. No deposition of grains is seen in this layer. During the differentiation of the proembryo small grains begin to appear in the cells of the outer layer of the outer integument.

These grains first appear in the micropylar part and slowly the deposition spreads towards the chalazal end. In the mature seed these cells are completely filled with these grains (Fig. 46), which are most probably of the nature of tannins.

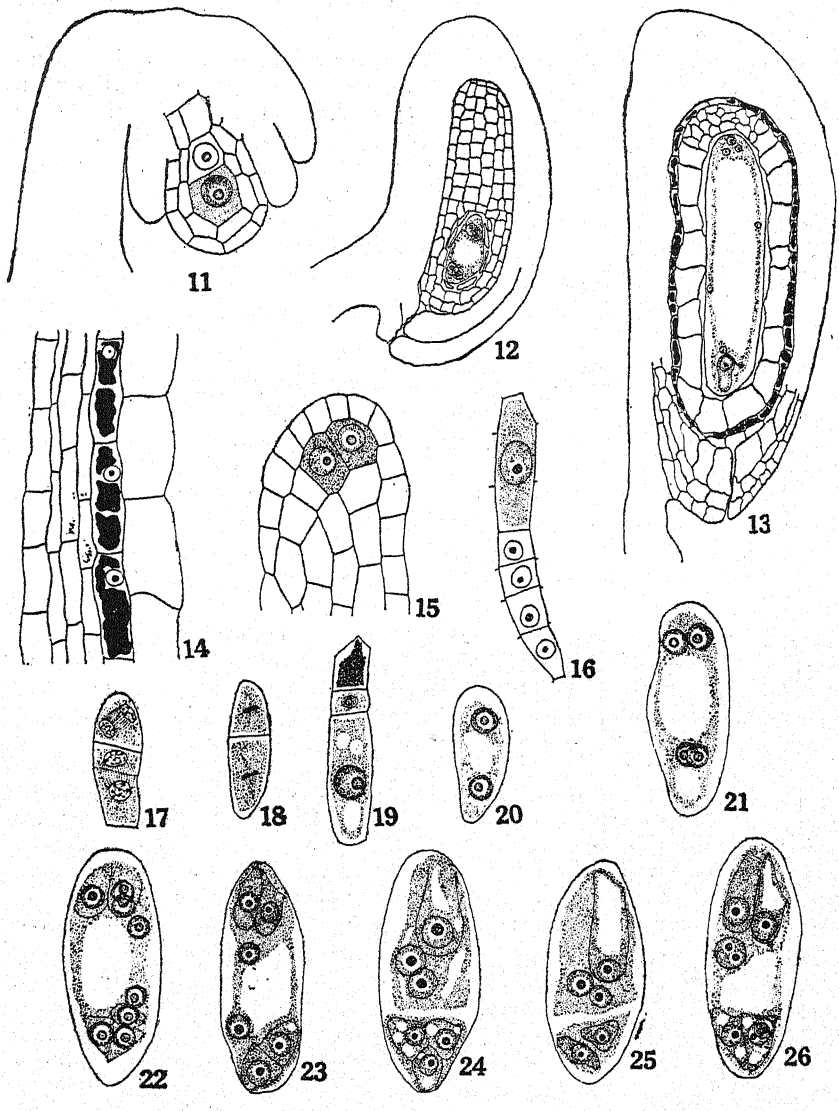
MEGASPOROGENESIS

The archesporium in the nucellus consists of 1 to 3 cells situated below the epidermis (Fig. 15). All these archesporium cells do not function, but only one develops further. It cuts off a parietal cell by a periclinal division and becomes the megaspore-mother cell (Fig. 11). The other archesporial cells merge into the surrounding cells of the nucellus, as observed by Frisendahl (1937) in *Elatine*.

The functioning megaspore-mother cell rests in the beginning on one or two supporting cells (Fig. 11). Their number increases up to four or five as the megaspore-mother cell prepares for the meiotic divisions (Fig. 16). The tetrad formation has been closely followed. The nucleus is generally situated in the middle or slightly in the upper part of the megaspore-mother cell (Fig. 16). Consequently the two dyad cells are either equal or the upper one may be slightly smaller (Figs. 17 and 18). Both the dyad cells divide once again simultaneously (Figs. 17 and 18). The tetrad is generally T-shaped, but at times it is also linear. In one case it was observed that the micropylar dyad cell had failed to divide and thus a row of three, *i.e.*, two megaspores and a dyad cell, had been formed. The upper three megaspores degenerate, while the chalazal cell is always functional. Generally the miropylar megaspores begin to degenerate first (Fig. 19). The degeneration then extends to the other non-functional megaspore.

The functioning megaspore increases in size. The vacuoles appear (Fig. 19) and it becomes bi-nucleate (Fig. 20). Both these nuclei divide twice. This leads to the formation of a typical 8-nucleate embryo-sac (Figs. 21 and 22). The mature embryo-sac before fertilization consists of one egg, two synergids, two polar nuclei and three antipodals.

The egg has the usual flask-shaped appearance. It has a vacuole in the micropylar part and the nucleus in the chalazal region (Figs. 24 and 25). In certain cases the egg was seen to be rather elongated and had almost half the length of the embryo-sac (Fig. 25). Rarely the egg was found to be devoid of any vacuole (Fig. 26). The synergids are shown in Fig. 23. They are pear-shaped in form and have quite prominent hooks. Mauritzon (1936) has recorded the presence of hooks in the synerigds of many plants from the Parietales. In young synergids the vacuole is absent (Fig. 23), but as these develop further, vacuolation appears in the chalazal region. Sometimes the vacuole may develop in the micropylar part and the synergids may look like an egg (Fig. 26), as described by Joshi and Kajale (1936) in *Tamarix dioica*. Such synergids are generally observed in association with those egg cells which had no vacuoles in their micropylar region. The two polar nuclei



Figs. 11–26.—*Bergia ammanioides.* Figs. 11–13. Three stages in the development of the ovule. Fig. 14. A part of integuments and nucellus as seen in longitudinal section. Fig. 15. Young nucellus showing two hypodermal archesporial cells. Fig. 16. A megaspore-mother cell mounted on a row of four supporting cells. Figs. 17–26. Different stages in the development of the embryo-sac from the dyad stage onwards. In Fig. 26 an egg-like synergid is seen. Figs. 11 and 14–26 (× 760). Figs. 12–13 (× 340).

fuse below the egg nearly in the middle of the embryo-sac and form a secondary nucleus (Figs. 24–26).

The chalazal end of the embryo-sac is occupied by three antipodals (Figs. 22–26). They are organised more or less simultaneously with the egg-apparatus (Fig. 22). In the beginning they are completely filled with cytoplasm, but later vacuoles begin to appear in them (Figs. 23, 24 and 26). They persist up to fertilisation, but no trace of them is seen afterwards. A number of abnormal cases of embryo-sac development have been reported by Frisendahl (1927) in *Elatine*, but no such variation was observed in the present material.

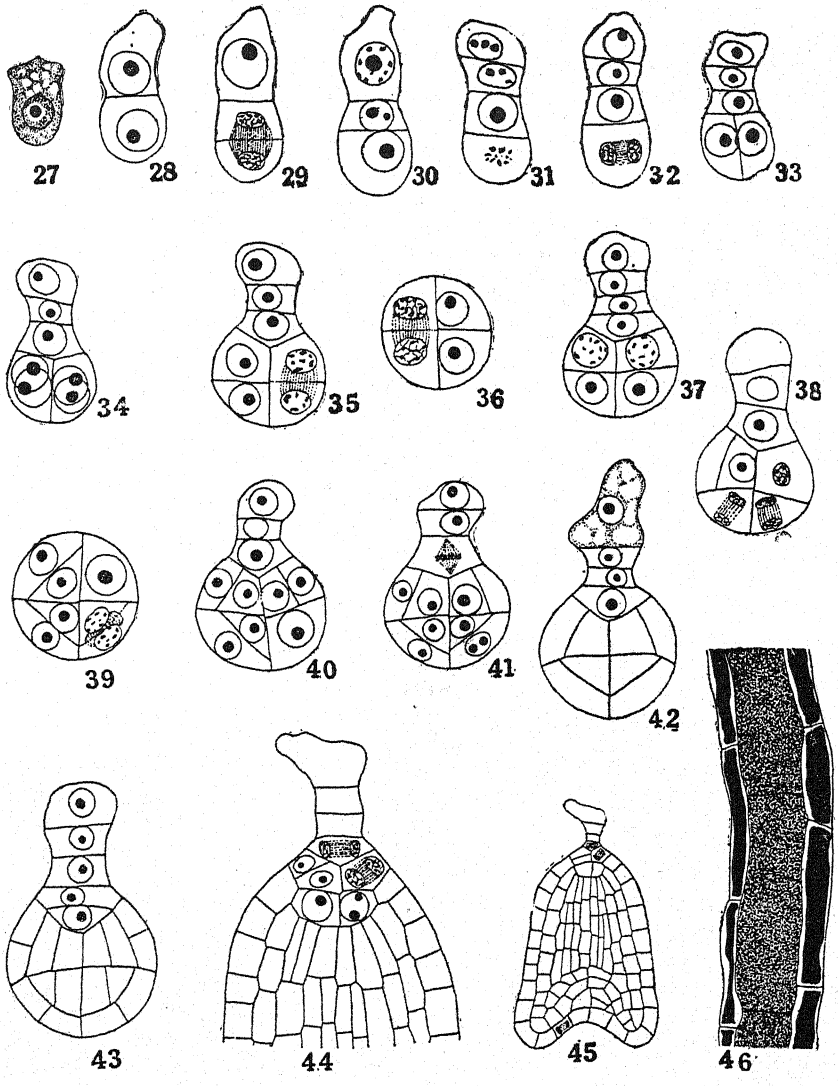
The Embryo

After fertilization the oospore divides transversely into an apical and a micropylar cell (Fig. 28). The two cells thus formed divide once again transversely and a proembryo of four cells is organised (Figs. 29–31). Both these cells however, do not divide simultaneously. Generally the apical cell divides first (Fig. 29) and for sometime the proembryo consists of three cells only. The further behaviour of these four cells is as follows.

The apical cell is directly concerned in the formation of the embryo proper. By two longitudinal divisions at right angles to each other it divides into four cells (Figs. 32–34). The four cells now divide transversely to form an octant composed of two tiers of four cells each (Figs. 35–37). The dermatogen now begins to appear. The first periclinal walls generally appear in the basal tier and this is followed by their appearance in the apical tier (Figs. 38–41). After the completion of the dermatogen, the two tiers do not develop simultaneously. The basal one is more active than the other. By a series of longitudinal and transverse divisions it forms the hypocotyl and radicle (Fig. 45). In the apical tier the divisions take place more in the longitudinal plane to keep pace with the rapidly growing micropylar tier. In the transverse direction the cells of the apical tier divide only once or twice before the cotyledons appear, but after the stem and cotyledon initials have appeared, this tier grows more actively.

The second cell from the apex of the proembryo is responsible for the completion of the root-tip. It divides by a transverse wall into two cells (Figs. 41 and 42). The one towards the micropyle does not divide further and forms part of the suspensor to be described shortly. The other cell adjacent to the embryonal mass is the hypophysis. It divides once again transversely into two cells (Fig. 43). Out of them the cell on the suspensor side by longitudinal and periclinal divisions completes the epidermis of the root apex and forms the root cap, while the other cell by its further differentiation contributes to the periblem of the radicle.

The two remaining cells of the proembryo do not divide either by transverse or longitudinal walls and along with the sister cell of the hypophysis form the suspensor, which thus finally consists



Figs. 27–46—*Bergia ammanioides.* Figs. 27–45. Various stages in the development of the embryo. In Fig. 44 formation of the root-tip is shown. Fig 46. A part of the testa and the persistent layer of the nucellus from the mature seed in transverse section. Figs. 27–44 and 46 (× 760). Fig. 45 (× 360).

of three cells (Fig. 44). The micropylar cell of the suspensor becomes slightly enlarged and may be somewhat haustorial in function. The suspensor persists upto the stage shown by Fig. 45.

The embryo development in *Bergia ammanioides* thus may be said to correspond to the *Capsella*-type. It differs from that of *Capsella* in the following respects. In *Capsella* the apical cell of the two-celled proembryo does not divide any more transversely and directly forms the embryo proper. In *Bergia* this cell divides once more transversely and the resulting apical cell then forms the embryo. There is also difference in the differentiation of the hypophysis of these two plants. In *Capsella* it comes from the micropylar cell of the two-celled proembryo, while in *Bergia* it differentiates from the penultimate cell which results by a transverse division of the apical cell of the two-celled embryo. In other words, leaving the suspensor, the embryo in *Capsella* is completed by both the cells of the two-celled proembryo. On the other hand, in *Bergia* it is formed from the apical cell only. The suspensor in *Capsella* is quite long and has a well-developed haustorial cell. In *Bergia*, the suspensor consists of three cells and lacks any large haustorial cell.

Endosperm

The primary endosperm nucleus divides a number of times before the division of the oospore in a free nuclear fashion. Some of these nuclei accumulate in the chalazal part of the embryo-sac, while some lie scattered in the peripheral lining of the protoplasm. The free nuclear endosperm later becomes cellular. Wall formation starts in the micropylar region and then extends to the chalazal extremity. As reported by Frisendahl (1927), the condition in *Elatine* is different. Here, wall formation in the endosperm starts just in the opposite direction, *i.e.*, from the chalazal to the micropylar end. The endosperm is gradually utilised by the developing embryo. In the mature seed it is all absorbed except one or two layers. The cells of these layers are full of starch grains.

Summary

The archesporium in each anther-lobe consists of 1 to 3 rows of hypodermal cells. The primary parietal layer gives rise to 4 layers. The innermost of these forms the tapetum and the outermost forms the fibrous endothecium. The two middle layers are crushed during development. Tannin grains are abundantly deposited in the epidermis of the anther. The primary sporogenous cells directly form the pollen-mother cells. The mature pollen grain is 2-nucleate. There are 3 germinal furrows occupying the vertices of the triangular pollen grain.

The gynæcium consists of 4 to 5 carpels. The styles may be completely solid or partly hollow. The ovary wall consists of 4 layers, out of which the 2 inner layers become thick-walled, while the 2 outer layers remain parenchymatous.

The ovules are generally anatropous and are provided with two integuments and a short funicle. The micropyle is formed by both the integuments. The nucellus is massive to begin with, but in the seed, it is represented by a single layer of cells.

The archesporium in the ovule consists of 1 to 3 hypodermal cells. A parietal cell is cut off. The megaspore-mother cell generally forms a T-shaped tetrad, occasionally a linear tetrad. In one case the micropylar dyad cell had not divided and a row of 3 cells only was formed.

The embryo-sac is of the normal 8-nucleate type. The egg has the usual structure. The synergids are hooked. Rarely they show egg-like vacuolation. The antipodals consist of 3 cells. The endosperm is nuclear in the beginning, but later it becomes cellular. One or two layers of it persist in the mature seed.

The development of the embryo may be said to correspond to the *Capsella*-type. The suspensor consists of 3 cells only.

The testa of the mature seed consists of 2 layers one coming from each integument. The cells of the inner layer are thick-walled, while those of the outer are full of tannin grains.

My sincere thanks are due to Dr. A. C. Joshi for his kind interest and valuable suggestions throughout the investigation.

LITERATURE CITED

Bhargava, H. R. (1936) .. " The life-history of *Chenopodium album* Linn.," *Proc. Ind. Acad. Sci.*, B, **2**, 49–58.

Friesendahl, A. (1927) .. " Über die Entwicklung chasmogamer und kleistogamer Blüten bei der Gattung *Elatine*," *Medd. Goteborges bot. Tradgard-Acta horti Gothoburgensis*, **3**, 99–142.

Hooker, J. D. (1875) .. *Flora of British India*, **1**, London.

Jönsson, B. (1879) .. " Om embryosackens utveckling hos Angiospermerna," *Lunds Univ. Arsskr.*, **16** (quoted by Schnarf, 1931).

Joshi, A. C., and Kajale, L. B. (1936) " A note on the structure and development of the embryo-sac, ovule and fruit of *Tamarix dioica* Roxb," *Ann. Bot.*, **50**, 421–26.

Mauritzon, J. (1936) .. " Zur Embryologie einiger Parietales Familien," *Svensk. Bot. Tid.*, **30**, 79–113.

Müller, K. (1847) .. " Beiträge zur entwicklungsgeschichte des Pflanzenembryo," *Bot. Ztg.*, **5** (quoted by Schnarf, 1931).

Rendle, A. B. (1925) .. *The Classification of Flowering Plants*, Vol. **2**, *Dicotyledons*. Cambridge.

Schnarf, K. (1931) .. *Vergleichende Embryologie der Angiospermen*, Berlin.

HIGHER FUNGI OF THE PANJAB PLAINS

II. The Gasteromycetes

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IT is the second of the series of papers dealing with the Higher Fungi of the Panjab Plains. The fifteen species described here belong to the families *Hysterangiaceæ*, *Lycoperdaceæ*, *Geasteraceæ*, *Sphærobolaceæ*, *Nidulariaceæ*, *Phallaceæ* and *Clathraceæ*. Six of these species [*Lycoperdon pusillum* Pers., *Lanopila Wahlbergii* Fr., *Sphærobolus stellatus* Tode., *Cyathus stercoreus* (Sch.) deToni, *Ithyphallus aurantiacus* (Fr.) Fisch. and *Dictyophora indusiata* (Vent. and Pers.) Fisch.] have already been reported from India. Thus there are nine new records for this country.

Family HYSTERANGIACEÆ

Protubera Afr. Moeller Bras., *Pilzbl.* 1895, **7**, 10–22.

15. *Protubera maracuja* Afr., Bras. *Pilzbl.* 1895, **7**, 10–22.

Plants globose or subglobose, upto 7 cm. in diameter, dirty white. In fully formed specimens the surface is smooth, but in earlier stages it appears to be wrinkled; a character whereby it can be easily distinguished from other phalloid eggs. There is a tough outer wall surrounding the central homogeneous region, from which ridges penetrate into the latter and disappear in the gleba. The gleba is composed of a network of radially arranged oval, lobed, or branched masses; embedded in the gelatinuous matrix; generally arranged in a ring round the periphery, but in some cases occupying the centre; of dark olive green colour with white branching veins of sterile tissue penetrating into them.

Spores ellipsoidal to globose, hyaline to sub-hyaline, very slightly yellow; smooth, epispore medium thick; 3·7–4·6 μ in diameter, mean being 4·1 μ.

Sangla Hill; Lyallpur.—Completely or partially buried under soil. Ripe plants emit a very strong sweet odour. (Plate VII, Figs. 4, 5, 8).

A plant with very doubtful affinities, included by Boedijn (1932) in the family Phallaceæ; by Fischer (1933) in Hysterangiaceæ; and by Zeller (1939) in the family Protophallaceæ of the order Hysterangiales.

Family LYCOPERDACEÆ

Lycoperdon (Tourn.) Pers. *Syn. Meth. Fung.*, 1801, 140.

16. *Lycoperdon depressum* Bonorden, *Bot. Zeit.*, 1857, 611.

Plants obovoid or pyriform upto 2·5 cm. in height and upto 3 cm. in diameter with a thick mycelial base. Exoperidium of minute fugacious spines which coalesce to form small warts ; endoperidium membranous becoming smooth with age, tawny olive to Mikado-brown near the top and clay coloured at the bottom, opening by an irregular apical aperture. Sterile base well developed, cellular and of lighter colour than the gleba ; diaphragm absent.

Gleba greenish-yellow turning to Mikado-brown without columella ; capillitium threads hyaline ; sparingly branched and freely septate. Spores globose, 3·34–4·1 μ in diameter ; epispore hyaline to buff yellow, echinulate with a large central vacuole.

Gurdaspur.—Solitary or gregarious on rotten manure heaps (Plate VI, Fig. 3).

A collection from Sialkot closely resembles the above as to the exoperidium, capillitium and other gleba characters. But it differs in the smaller size, colour (which is Dresden-brown at the top and Buckthorn-brown at the bottom) and in having the sterile base scantily developed (practically absent in some specimens) (Plate VI, Fig. 4).

17. *Lycoperdon pusillum* Pers., *Jour. Bot.*, 1809, **2**, 17.

Plants globose or subglobose upto 2·3 cm. in diameter ; with a slender mycelial cord ; warm blackish brown at the top and snuff brown at the bottom. Exoperidium of small, whitish, mealy furfuraceous coat or of small distinct scales. Endoperidium papery smooth, opening in the ripe specimens by an irregular but a distinct mouth. Sterile base none.

Gleba olivaceous ; capillitium apricot yelllow, 3–3·8 μ in diameter, septate, freely branched and or not pitted on the surface. Spores globose, 4·8–5·95 μ in diameter ; epispore thin smooth, buff-yellow with a large vacuole.

Sangla Hill; Gurdaspur ; Sargodha.—Solitary on sandy soil. Very common and cooked as a vegetable during the rains (Plate VI, Fig. 1).

The species is characterised by its smaller size, absence of sterile base and smooth spores.

Lanopila Fries Fung. Natal.
in *K. Vetensk. Akad. Handlinger Stockholh*, 1848, 151.

18. *Lanopila Wahlbergii* Fr. Fung. Natal. in *K. Vetensk. Akad. Hand. Stockholm*, 1848, 151.

Plants globose or irregularly subglobose upto 4 cm. in diam. Exoperidium thin white, peeling off completely in the ripe plants.

Endoperidium papery cartilaginous of reddish brown colour, wearing away tardily by weathering to expose the gleba. When ripe the plants become detached from their point of attachment and roll about like " tumblers". Sterile base none.

Gleba olive brown, composed of long intertwined pitted, septate, branching capillitium threads, tapering at the ends. Spores spherical, medium chocolate-brown, rough, epispore medium thick; 5·6–7·4 μ in diameter, mean being 6·8 μ.

Sangla Hill.—On sandy soil, among grass and in cultivated fields, where it is largely destroyed by small rodents (Plate VI, Fig. 7).

The plant is like a Bovista in habit and absence of the subgleba, but differs in having a capillitium of long intertwined threads.

Fischer (1933) has recorded *Lanopila bicolor* as a distinct species from *L. Wahlbergii*, but as Lloyd has clearly shown the identity of the two cannot be passed by easily, so *L. bicolor* should be reduced to a synonym of *L. Wahlbergii*.

The Panjab plants are smaller in size than the type species and have pitted capillitium threads (a character not pointed out by any other author), and olive-brown gleba.

Disciseda Czern. *Bull. Soc. Imp. des. Natur. de Mosc.*, 1845, **18**, 153.
Syn. *Catastoma* Morgan, *Journ. Cincinnati, Soc. Nat. Hist.*, 1892, **14**, 142.

19. *Disciseda cervina* (Berk.) Cunningham,
Proceed. Linn. Soc. N.S.W., 1927, 52, 235.
Syn. *Disciseda subterrannea* (Peck.) Coker and Couch.
D. debrenceniensis (Hazsl.) Hollo's; *Catastoma subterranea* Peck.

Peridium globose or depressed globose; upto 2·3 cm. in diameter. Exoperidium in the form of a sand case, which breaks away in the ripe condition leaving a part still attached to the plant at the base (which is in reality the top as it grows *in situ*). Endoperidium thin, smooth, or reticulate, opening by a distinct mouth (formed basally).

Gleba dark brown; capillitium pale brown, of short separate threads, blunt at the ends (characteristic of the genus). Spores spherical, globose; reddish-brown, echinulate, epispore medium thick, 5·6–6·7 μ in diameter mean being 6·0 μ.

Sangla Hill.—Hypogeous in sandy soil, occurring singly or rarely two plants united together (Plate VI, Fig. 2).

According to Lloyd *Catastoma circumcissum* and *Catastoma subterranea* are large and small spored varieties of the same species. In the former the spores are 4–5 μ, while in the latter they are from 6–8 μ. Writer's specimens with spore 5·6–6·7 μ serve as a good connecting link between the two.

Family GEASTRACEÆ

Geastrum Pers., *Syn. Meth. Fung.*, 1801, 131.

(Syn. *Geaster* (Mich.) Fries, *Syst. Mycol.*, 1832, **38.**)

20. *Geastrum minus* (Pers.) Cunningham, *Proc. Linn. Soc., N. S. Wales*, 1926, **51,** 81.

Syn. *Geaster minimus* Schw ; *Geastrum quardifidum* var. *minus* Persoon

Plants globose or subglobose. Exoperidium recurved, split to about the middle into 4–6 segments. Mycelial layer adnate, sometimes completely or partially separating. Fleshy layer closely adnate, smooth on the limbs of the exoperidium, but rimose on the segments. Endoperidium subglobose or elliptical, covered with minute granules ; pedicellate, pedicel short, but distinct. Mouth definite with a well-marked circular depressed groove.

Gleba ferruginous ; columella slender ; indistinct in ripe specimens ; capillitium threads amber brown, 3·2–3·8 μ in diam. Spores globose, Argus-brown to Brussel's brown ; sparsely but distinctly verrucose ; 3·72–4·65 μ in diam., mean being 4·27 μ.

Gurdaspur.—Solitary on the ground. Epigeous. Not common (Plate VI, Fig. 6).

21. *Geastrum velutinus* Morgan, *Jour. Cin. Soc. Nat. Hist.*, 1895, **18,** 38.

Plants obovate, bluntly pointed, superficial, attached to the substratum by basal mycelial threads. Exoperidium split to about the middle into 4–5 pointed rays covered with debris but becoming perfectly smooth with age. Endoperidium sessile ; subglobose ; upto 2 cm. diameter, pallid brown, very finely tomentose, base covered by the basis of the rays ; opening by a small, broadly conical, fibrillose mouth seated on a depressed silky zone.

Gleba umber ; columella distinct, clavate ; capillitium threads Brussel's brown 3·36–4·6 μ in diam. Spores globose Ausique brown to Brussel's brown 3·35–4·1 μ in diam. ; epispore closely and distinctly echinulate.

Sangla Hill.—Epigeous. Solitary on the ground. Rare (Plate VII, Figs. 6, 7). The plants are provisionally so referred and probably represent a local form differing from the type in having a smaller size, smooth exoperidium and the outer and inner layers of the exoperidium not at all separating from each other.

Family SPHÆROBOLACEÆ

Sphærobolus Tode, *Fung. Meckl.*, 1790, **1,** 143.

22. *Sphærobolus stellatus* Tode, *Fung. Meckl.*, 1790, **1,** 143.

Plants subspherical upto 2 mm. in diameter, at first yellowish brown in colour but ultimately becoming whitish. The fruit body

opens by 4–5 lobes in a stellate manner, exposing the central black glebal ball surrounded by a yellowish ring. On exposure to the air outer translucent yellow layer (receptaculum) suddenly reverses itself and throws the little central black ball containing spores upto a distance of some feet. The reversed receptaculum then appears as a colourless drop of jelly resting on the lobes of the outer peridium.

Spores smooth, globose, oval, oblong, some irregular; 4·25–6 × 8·75–11 μ.

Sangla Hill; Gurdaspur.—Common on old manure heaps (Plate VII, Fig. 9).

Family NIDULARIACEÆ

Cyathus Hall., *Hist. Stirp. Helv.*, 1768, **8**, 127.

23. *Cyathus stercoreus* (Schw.) de Toni, in *Sacc. Syll. Fung.*, 1888, **7**, 40.

Plants cup-shaped upto 1·2 cm. in height, sessile and tapering towards the base, gregarious and usually crowded. Outer surface tawny to gray brown at maturity covered with thick woolly hairs, which wear off with age, the cups becoming almost smooth; inner surface smooth, not striate, of lighter colour, epiphragm delicate, rupturing and disappearing in a short time. Mouth smooth. Peridioles nearly black; smooth; discoid; with a funiculus; 1·7–2·3 mm. in diam. Spores hyaline; smooth; globose, oval or oblong thick-walled, 23·2–36 × 17·5–28 μ.

Sangla Hill; Gurdaspur.—Very common on manure heaps and rotten wood (Plate VI, Fig. 5).

Family PHALLACEÆ

Ithyphallus (Fr.) Fischer, *Ann. Jard. Bot. Buit.*, 1886, **6**.

24. *Ithyphallus rubicundus* (Bosc.) Fischer, *Jahrb. Bot. Gart. U. Mus.*, 1886, **5**, 50.

Syn. *Ithyphallus aurantiacus* (Mont.) Fischer.

Eggs globose or ovoid, upto 3 cm. in diameter, dirty-white or white with a basal mycelial cord-like attachment. Stalk upto 10 × 2 cm., white, tapering towards the top and perforated at the apex, with the campanulate pileus hanging from the top. Pileus granular, not reticulate, sometimes the granules fuse to form low, parallel ridges. Veil very rudimentary, hidden under the pileus or found attached in small patches on the stalk.

Gleba olive green with a very strong odour. Spores elliptic, 3·6 × 2·1 μ.

Sangla Hill.—Solitary or in groups on the ground. Common (Plate VI, Figs. 8, 9, 10).

The specimens collected in the Panjab closely agree with the description and figures of the species presented by other writers

excepting colour. The colour is generally described as red, but it is white in the Panjab plants, which thus resemble *Ithyphallus Ravenelii*, a species restricted to North America. The variability of the species can be better judged from the number of synonyms quoted by Cunningham (1931).

Itajahia Alfr. Moeller Brasil., *Pilzb.*, 1895, 79.

25. *Itajahia galericulata* Alfr. Moeller Brasil., *Pilzb.*, 1895, 79.

Syn. *Phallus roseus* Delile ; *Itajahia rosea* (Delile) Fischer.

Eggs globose, brown, upto 5 cm. in diam., with a number of basal mycelial cords. Stalk upto 8 cm. long, hollow, broad towards the apex where it is bent outwards forming a distinct apical collar, covered over with a characteristic well-developed cap, which has a regular or lacerated margin. The cap separates when the stalk elongates after the rupturing of the volva at the apex. Receptacle globose, with white lamellate plates of sterile tissue traversing the gleba.

Gleba dark olive-green ; viscid ; foetid ; permeating the sterile plates upto the inner surface. Spores, elliptic, $4 \cdot 3 \times 2 \cdot 25\ \mu$.

Sangla Hill.—Solitary or in groups on decaying vegetable debris under trees of *Salvadora oleoides* and *Capparis aphylla*. Common (Plate VI, Fig. 11 and Plate II, Fig. 3).

Characterised by the structure of the pileus and the apical cap which are both peculiar to the genus.

Dictyophora Desvaux, *Jour. de Bot.*, 1809, **2**, 88.

26. *Dictyophora indusiata* (Vent. and Pers.) Fischer, *Unter Phalloid. Surinam*, 1928, 28.

The writer has seen a specimen of this species collected from Lyallpur in the Museum of the Botany Department of the Panjab University, Lahore.

The species is characterized by the white indusium and receptacle and by the rugulose reticulate surface of the pileus.

Family CLATHRACEÆ

Lysurus Fries *Syst. Myc.*, 1822, **2**, 285.

27. *Lysurus borealis* (Burt.) P. Henn., *Hedw.*, 1902, 167, XLI.

Eggs subglobose 1·6 cm. in diam. Receptacle $3 \times 1 \cdot 2$ cm. Stem pink, cylindrical, hollow, divided apically into 6 arms, which are erect, hollow, narrowly lanceolate, 1·3 cm. long, attenuated, transversely grooved, orange. Gleba olive-green, borne on the inner surface and edges of the arms. Spores elliptic, $3 \cdot 9 \times 2 \cdot 2\ \mu$.

Sangla Hill.—On sandy soil. Rare (Plate VII, Fig. 10).

In one plant two arms are united with each other just below their apices. The Panjab specimens closely resemble the " stocky forms" of this species reported from England and U.S.A. and figured by Lloyd (*Synopsis of the Known Phalloids*, p. 36, Fig. 40).

Cunningham (1931) has proposed a new combination, *Lysurus sulcatus* (Cke. and Mass.) for this species.

Simblum Klotsch Hook., *Bot. Misc.*, 1831, **2**, 164.

28. *Simblum sphærocephalum* Schlecht, *Linnea*, 1862, **31**, 154.
Syn. *Simblum rubescence* Gerard.

Eggs globose to elongated, yellowish or pale yellowish in colour, never white, upto 1·6 cm. in diam. and 1·8 cm. in height, attached below by numerous yellowish or white mycelial cords. Receptaculum bright or pale orange or white, upto 2·4 cm. in height. Stalk hollow, filled with mucilage, at least in early stages, upto 2 cm. in height and ·8 cm. in diameter tapering towards the base, orange, white or pale orange at the top and white at the base, bearing a globose, depressed globose, compressed from the sides or ovoid head, upto 1·2 cm. in diameter and ·75 cm. in height. Meshes from few to indefinite, polygonal, hexagonal, or elongated at the base and forming a network only at the top; distinctly marked off from the stalk or passing insensibly into it.

Bars of the net narrow or broad, flat or slightly concave on the outside, with a regular or irregular margin and even or transversely wrinkled surface. The sides are always plicate and bear the gleba. In a section the bars are hollow and their cavity is continuous, which contains mucilage.

Gleba olive-green or almost dark on drying, emitting a strong odour. Spores elliptic, $4·2 \times 2·1\ \mu$.

Rohtak.—Solitary or in groups. Very common in grassy plots (Plate VII, Fig. 1).

A very common plant which appears in large numbers with the first shower of the monsoon rains. It differs widely from the type species in the size and number and form of meshes; but it presents the bright orange colour typical of the species.

A few plants of this species were sent to Dr. Coker who referred them to *Simblum gracile*, a form which differs from it only in colour. The writer believes that the colourless forms of this species are mistaken for *S. gracile*.

Colus Cav. et Sech. *Ann. Scien. Natur.*, 2 Ser., 1835, **3**, 251.

29. *Colus hirudinosus* Cav. et Sech., *Ann. Scien. Natur.*, 2 Ser., 1834, **3**, 251.

Plants small upto 3·2 cm. in length. Receptacle borne on a stalk and continued along it in the form of column. Stalk fluted and

four-angled with transverse grooves on it. Receptacle consists of lower vertically elongated and upper isodiametric meshes. In the specimen at hand the receptacle is divided into two distinct halves which have no connection with each other. This may be regarded as an abnormal condition until some more plants are found. Gleba olive-green with a strong odour. Spores elliptic, $3 \cdot 85 \times 2 \cdot 15\ \mu$.

Sangla Hill.—On sandy soil. Rare (Plate VII, Fig. 2).

The plant is characterized by the fluted (not cylindrical) stem, and the meshes of the receptacle which are vertically elongated lower down but are isodiametric at the top.

Although Cunningham (1931) recognizes only one valid species of the genus which presents little or no variation from the original description and figure of Tulsane, yet the writer is convinced that the Panjab plant should be referred to the genus *Colus*. It strongly differs from the type species in having a fluted four-angled stem and the receptacle divided into two separate halves, but realising the danger of erecting new species on single specimens it has been referred to for the present under *C. hirudinosus* as a local form.

ACKNOWLEDGEMENTS

In the end the writer wishes to express his feelings of gratitude to Dr. B. B. Mundkur of the Imperial Agricultural Research Institute, New Delhi, for the keen interest and unfailing help rendered during the progress of this work.

BIBLIOGRAPHY

Boedijn, K. B. (1932) .. "The Phallineæ of Netherlands East Indies," *Bull. Jard. Bot. Buitenzorg.*, Ser. 3, **12**, 71–103.

Butler, E. J., and Bisby, G. R. (1931) "Fungi of India," *Imp. Comp. of Agr. Res. Ind. Sci. Mono.*, Calcutta, **18**, (1), 273.

Coker, W. C., and Couch, J. N. (1928) "Gasteromycetes of Eastern United and Canada," North Carolina University Press.

Cunningham, G. H. (1926) .. "The Gasteromycetes of Australasia—IV. Species of the genus *Geaster*," *Proc. Ind. Linn. Soc. N. S. Wales*, **51**, 72–94.

———— (1926) .. "The Gasteromycetes of Australasia—VI. The genus *Lycoperdon*," *Ibid.*, **51**, 627–42.

———— (1927) .. "The Gasteromycetes of Australasia—VII. The genera *Disciseda* and *Abstoma*," *Ibid.*, **52**, 235–45.

———— (1927) .. "The Gasteromycetes of Australasia—IX. Keys to the genera and species of the Lycoperdaceæ," *Ibid.*, **52**, 247–57.

———— (1931) .. "The Gasteromycetes of Australasia—X and XI. The Phallales," *Ibid.*, **56**, 1–15, 182–200.

Fischer, Ed. (1933) .. " Gasteromycetæ. In Engler and Prantl," *Die Natürlichen Pflanzenfamilien*, 2 ed. 7*a*.

Lloyd, C. G. (1902) .. " The Geasteræ," *Cinn. Ohio.*

———— (1906) .. " The Nidulariaceæ," *Cinn. Ohio.*

———— (1909) .. " Synopsis of the Known Phalloids," *Cinn. Ohio.*

Narasimhan, N. J. (1932) .. " The Phalloideæ of Mysore," *J. Ind. Bot. Soc.*, **11**, 253.

Petch, T. (1908) .. " The Phalloideæ of Ceylon," *Annals. Roy. Bot. Gerad. Peradeniya*, **4**.

Zeller, S. M. (1939) .. " New and Noteworthy Gasteromycetes," *Mycologia*, **31**, 1–32.

EXPLANATION OF PLATES

PLATE VI

(All natural size)

FIG. 1. *Lycoperdon pusillum* Pers.

FIG. 2. *Disciseda cervina* (Berk.) Cunningh.

FIG. 3. *Lycoperdon depressum* Bonor.

FIG. 4. *Lycoperdon depressum* Bonor. Specimens from Sialkot.

FIG. 5. *Cyathus stercoreus* (Schw). de Toni.

FIG. 6. *Geastrum minus* (Pers.) Cunningh.

FIG. 7. *Lanopila Wahlbergii* Fr.

FIGS. 8-9. *Ithyphallus rubicundis* (Bosc.) Fischer.

FIG. 10. L. S. of egg, *Ithyphallus rubicundis* (Bose.) Fischer.

FIG. 11. L. S. of egg, *Itajahia galericulata Alf.* Moeller.

PLATE VII

FIG. 1. *Simblum sphærocephalum* Schlecht, Nat. Size.

FIG. 2. *Colus hirudinosus* Cav. et Sech., Nat. Size.

FIG. 3. *Itajahia galericulata* Alf. Moeller, × ½.

FIG. 4. *Protubera maracuja* Alf. Moeller, Nat. Size.

FIG. 5. L. S. of *P. maracuja* Alf. Moeller, × ½.

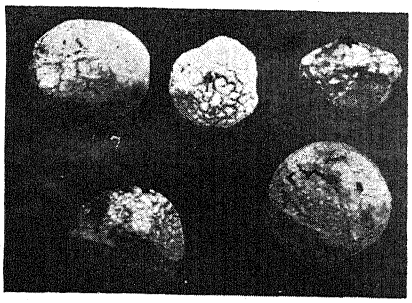
FIG. 6. *Geastrum velutinus* Molg. (button stage and section of the same) Nat. Size.

FIG. 7. *Geastrum velutinus* Morg., Nat. Size.

FIG. 8. *Protubera maracuja*, very young stage, Nat. Size.

FIG. 9. *Sphærobolus stellatus* Tode.

FIG. 10. *Lysurus borealis* (Burt.) P. Henn.



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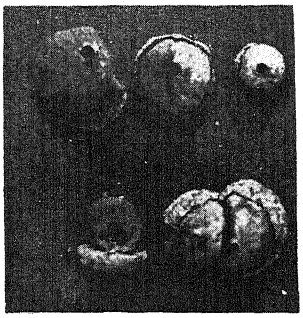

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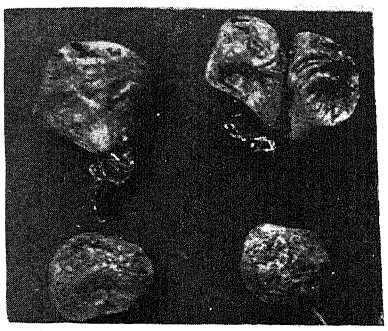

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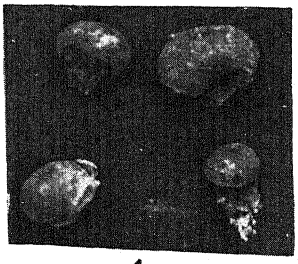

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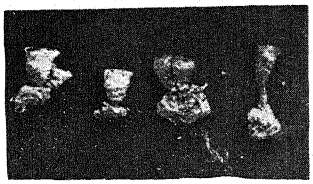

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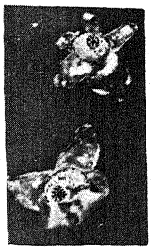

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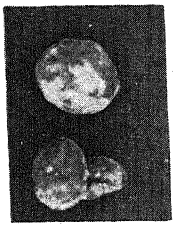

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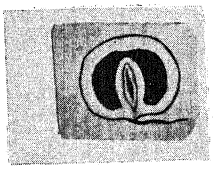

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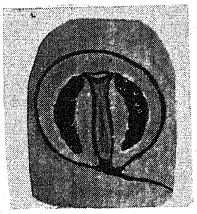

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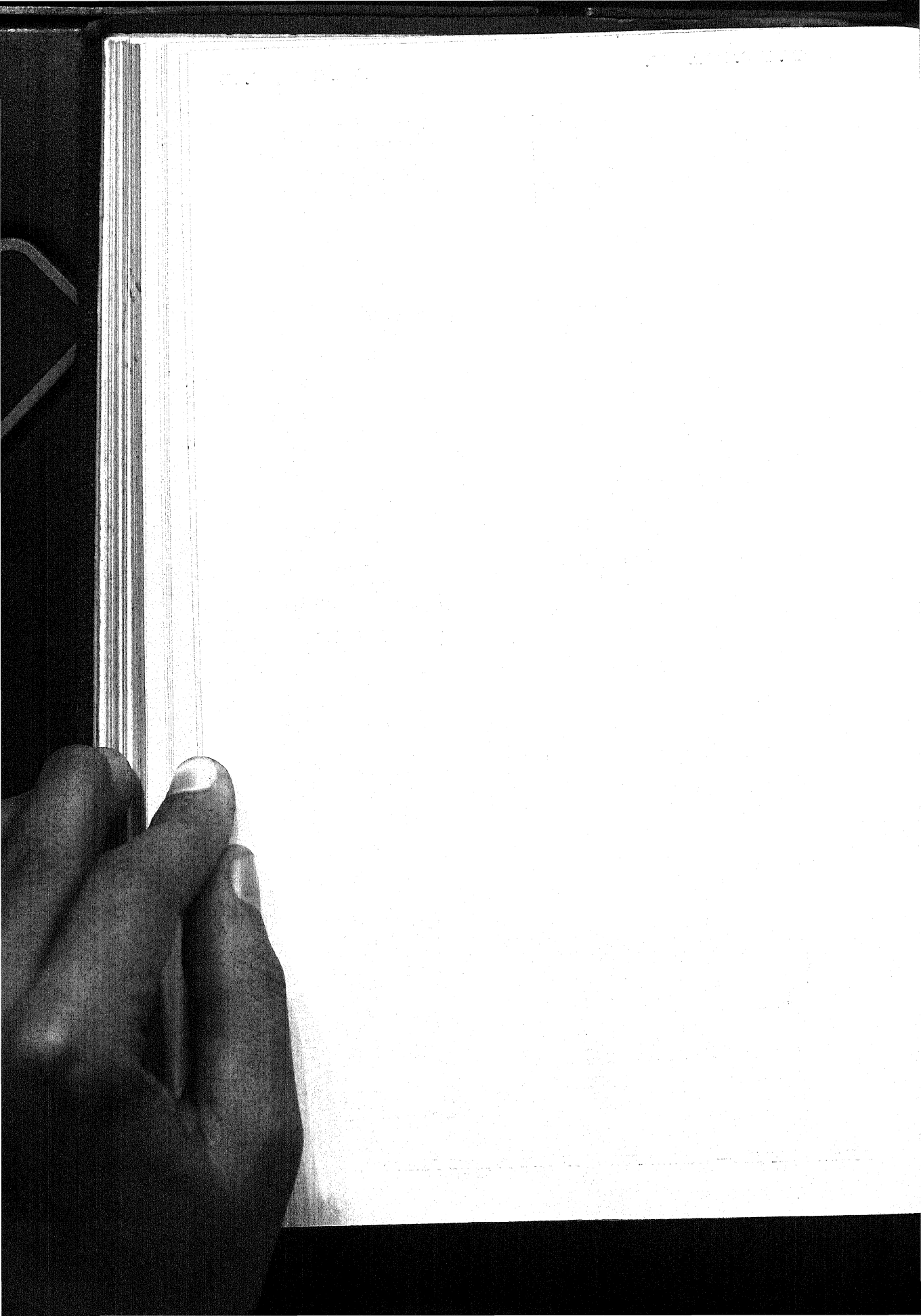
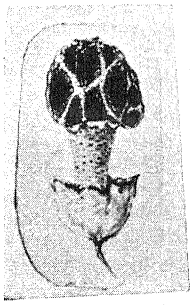
SULTAN AHMAD—*HIGHER FUNGI OF THE PANJAB PLAINS*





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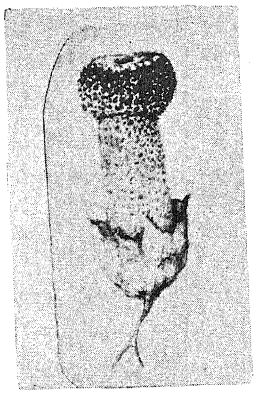

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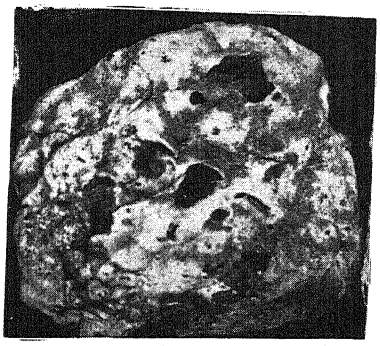

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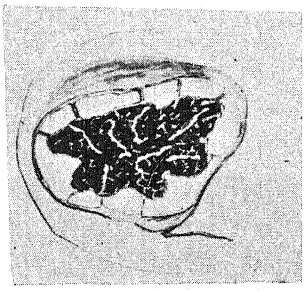

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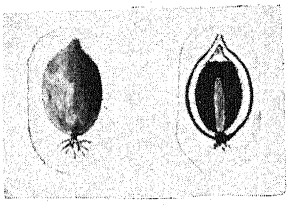

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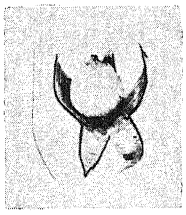

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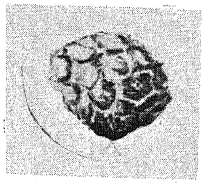

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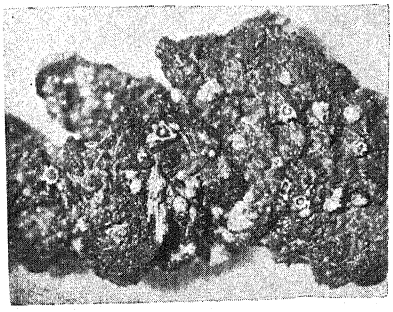

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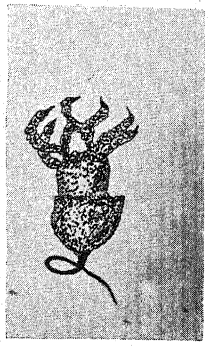

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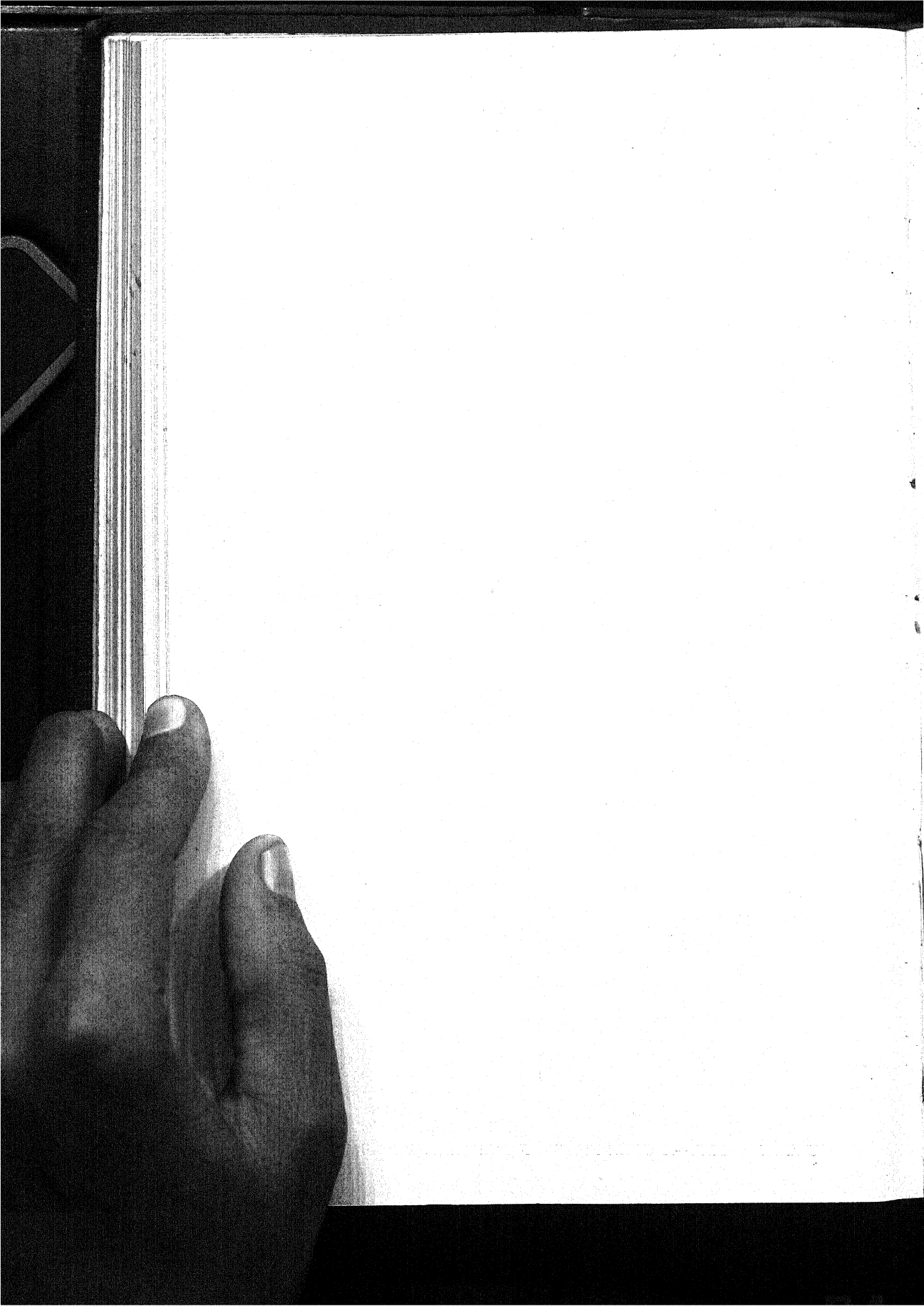
SULTAN AHMAD—*HIGHER FUNGI OF THE PANJAB PLAINS*



DEVELOPMENT OF EMBRYO-SAC AND ENDOSPERM-HAUSTORIA IN SOME MEMBERS OF SCROPHULARINEÆ

IV. *Vandellia hirsuta* Ham. and *V. scabra* Benth.

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Received for publication on November 9, 1939

Some contributions dealing with the development of the embryo-sac and endosperm-haustoria in a few members of the Scrophularineæ have been already published by the author (1937, 1939*a* and 1939*b*). In the third paper of the series (1939*b*), the author has referred to the presence of a single uni-nucleate chalazal haustorium in *Limnophila heterophylla* and *Stemodia viscosa* and advanced the view that the increased bulk of its nucleus probably makes up for the reduced number of nuclei. In the same paper the author has described the dilated end of the embryo-sac in *Stemodia* with the large antipodals loosely arranged in this region. This character is an innovation in the family, where the presence of a tapering chalazal end with the included small antipodals happens to be a constant feature. According to the author this enlarged chalazal end with the innumerable starch grains has a highly significant role in the nutritional physiology of the embryo-sac.

The relation of the early divisional stages of the primary endosperm nucleus to the organisation of the haustoria and endosperm has been stressed by Schmid (1906), Glišić (1936–37) and other investigators. In the chart presented below the first three rows indicate the sequence of divisons and the trend of the haustorial number and development in the several members already studied by the author (Iyengar, 1937, 1939*a*, 1939*b*), while the other two rows are introduced to point out the phylogenetic tendency of the haustoria in the family as a whole.

The first row represents the *Verbascum*-type. *Isoplexis*, *Celsia*, *Scrophularia* (Schertz, 1919), *Verbascum* (Schmid, 1906) and others conform to this. The last figure in the row indicates that there are four haustorial cells at each end of the embryo-sac even during the older stages.

In the *Alonsoa*-type, the first two divisions are transverse and the next two are longitudinal. These result in the organisation of four micropylar and two chalazal haustorial cells. Invariably the two chalazal haustorial cells develop into a single bi-nucleate body by the dissolution of the partitional wall. *Alonsoa* and *Sopubia* come under this type, but the latter shows a slight variation. Here the four micropylar cells fuse together in later stages to form a

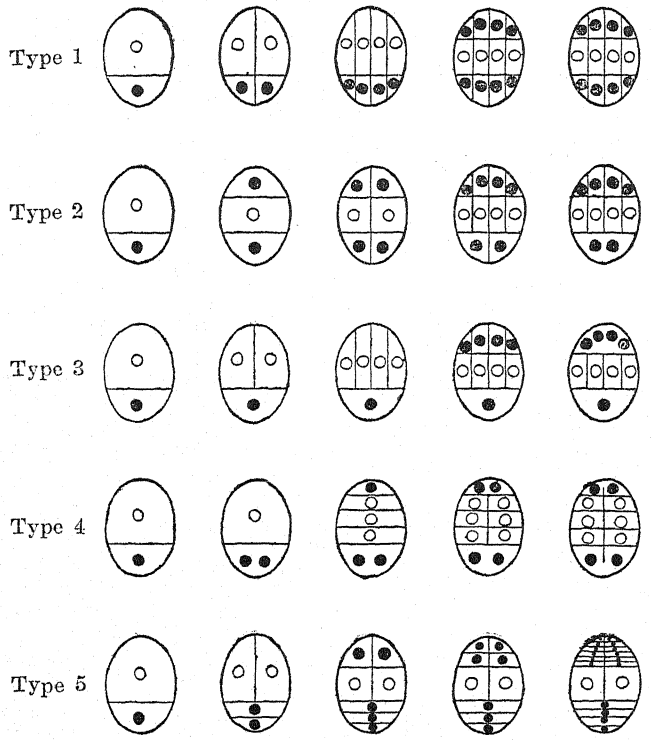


Chart representing the development of endosperm and endosperm-haustoria in (1) *Verbascum*-type, (2) *Alonsoa*-type, (3) *Limosella*-type (4) *Paulownia*-type and (5) *Gratiola*-type.

single tetra-nucleate body. *Pedicularis* (Schmid, 1906) resembles *Sopubia*, but possesses the bi-nucleate chalazal haustorium and tetra-nucleate micropylar haustorium from the commencement.

In the *Limosella*-type of Glišić (1936–37) the chalazal haustorium is uni-nucleate from the beginning. *Stemodia* and *Limnophila* conform to this type in the sequence of divisions, but differ from *Limosella* (Svensson, 1928) in having during later stages a single tetranucleate micropylar haustorium instead of four uni-nucleate ones.

Paulownia (Millsaps, 1936) is regarded here as a type by itself. Both the chalazal and micropylar haustoria are bi-nucleate from the beginning. The *Gratiola*-type occupies a higher place than *Paulownia* as regards the chalazal haustorium (which is a single uni-nucleate cell), but is lower with regard to the micropylar haustorium. While the micropylar haustoria show a tendency to reduce their number, the presence of a single uni-nucleate micropylar haustorium is still unheard of in Scrophularineæ, although it is commonly seen in some

members of the Bignoniaceæ (Mauritzon, 1935). A very interesting feature is met with in *Gratiola* (Glišić, 1933), where the chalazal haustorial cell instead of remaining uni-nucleate shows at times a tendency to divide, resulting in either two uni-nucleate cells or a single bi-nucleate cell. This is an important point in the evolutionary tendency of the haustoria.

While describing the endosperm haustoria in *Celsia*, the author (1939*a*) has called attention to the digesting and absorptive role of the integumentary tapetum, some of whose cells have been observed to undergo a conspicuous enlargement. This special function is of no small importance in the nutritional physiology of the embryo and endosperm, since its development takes place just at the time when the micropylar and chalazal haustoria begin to degenerate and are no longer competent to meet the growing demands of the developing endosperm and embryo. A similar situation is met with in the two species described in this paper.

Material and Methods

Both the plants were collected from Malpi harbour and the neighbouring islands in October 1936. As before, the materials were fixed in chromo-acetic acid solution with osmic acid. Sections were cut 8–12 microns thick and stained with Heidenhain's iron-alum hæmatoxylin.

Vandellia hirsuta Ham.

Longitudinal sections of the ovary (Fig. 1) show that the innumerable ovules are attached to the thick placenta by long funicles. The placenta is composed of large cells scattered among the smaller ones and in older stages it shows numerous large cavities which are specially numerous towards the periphery and have disorganising cell-walls, leading one to infer a probable lysigenous origin for them. All the placental cells contain starch, but it is the epiedermis that is specially rich in food materials. A similar condition is reported in *Utricularia* (Wylie and Yocom, 1923; and Kausik, 1938), and its significance will be explained later. Even the funicle shows its epidermal layer to have richer cell-contents.

The cells of the single integument are packed with starch grains and the inner layer forms the usual integumentary tapetum.

Embryo-sac.—The embryo-sac develops normally, but is peculiar in other ways. It completely disorganises the nucellus and its upper end grows out of the micropyle, enlarging considerebly, occupying the space between the funicle and placenta and pressing itself closely to them (Fig. 1). The position of the embryo-sac, its thin wall and the rich contents of the abutting epidermis in this region clearly indicate a nutritional relationship. It may safely be inferred that the extra-micropylar part of the sac directly absorbs nutrition from the placenta and funicle during the pre-fertilisation stages of its development. It is just similar to *Utricularia* (Wylie and Yocom

1928 ; and Kausik, 1938), but there the extramicropylar part continues to draw its nourishment even after fertilisation because of the development of the micropylar haustoria in this region. Varying grades of such development have also been reported in several other genera like *Avicennia*, *Congea* (Junnel, 1934), etc.

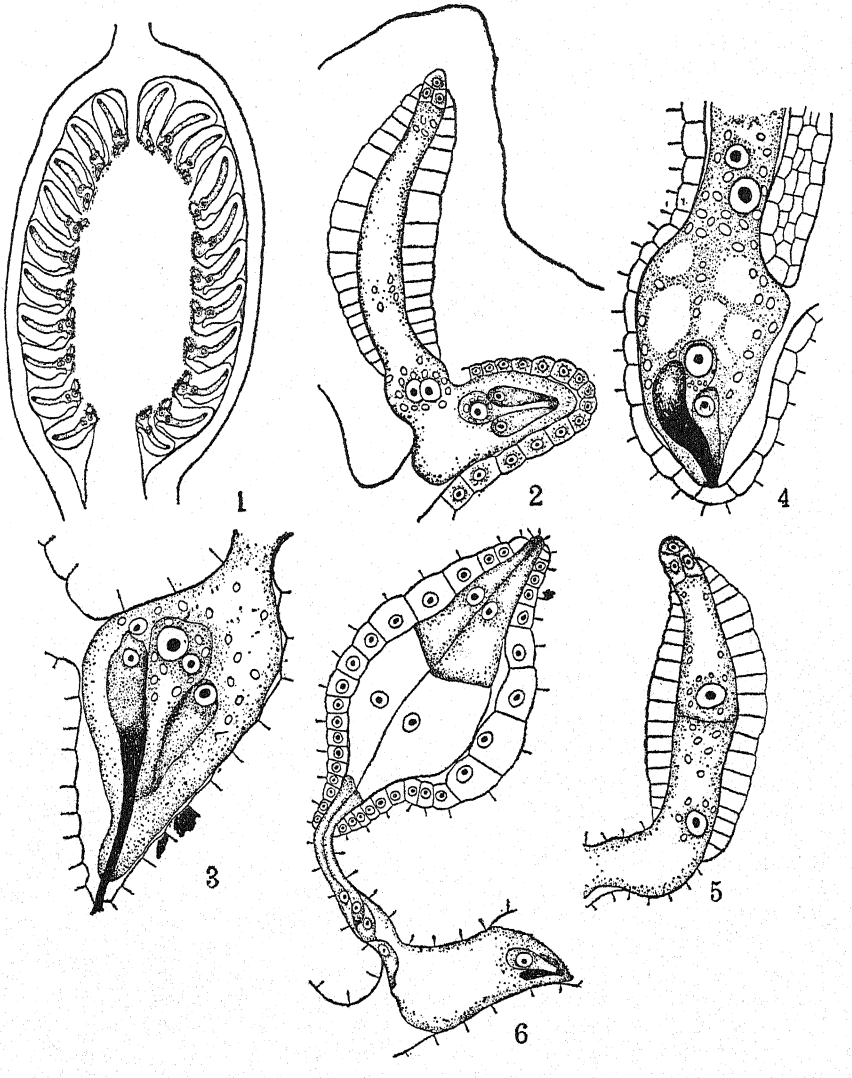
The enlarged extra-micropylar part of the embryo-sac (Fig. 2) contains the egg-apparatus, which is surrounded by several starch grains and a highly vacuolated cytoplasm. The two polar nuclei lie in the slightly dilated part of the embryo-sac just behind the constricted region. The inner portion is tubular and bent, and includes the three conspicuous antipodal cells at its basal end.

FERTILISATION.—Just before fertilisation the two polar nuclei fuse together to form the secondary nucleus. Since the egg-apparatus lies outside the micropyle, the pollen tube makes its way into it directly from the placenta and discharges the sperm nuclei. One of the synergids is destroyed during fertilisation. Figs. 3 and 4 show the sperm nuclei in the neighbourhood of the egg and secondary nucleus respectively, suggesting that syngamy and triple fusion occur in the normal way. Just after fertilisation the extra-micropylar part of the embryo-sac begins to shrink and become reduced in size.

The antipodals continue to persist till some time after fertilisation (Figs. 5 and 6). During older stages they shrivel and take a dark stain. A similar feature characterises *Gratiola* (Glišić, 1933), where the antipodals are clearly seen even after the formation of the mature embryo.

EMBRYO AND ENDOSPERM.—The fertilised egg is rather slow in its development and does not show any appreciable growth till the endosperm and haustoria are properly organised. It elongates into a tubular structure, which penetrates between the endosperm cells (Fig. 7) and divides transversely to form the primary embryonal cell and the suspensor. Further development is essentially similar to that of the other members already described by me.

The first division of the primary endosperm nucleus is followed by a transverse wall, resulting in the separation of a small chalazal chamber from a large micropylar one (Fig. 5). The second division, which takes place in the latter, is also transverse and separates a middle cell which is responsible for the body of the endosperm, while the two end cells give rise to the haustoria. The third division is longitudinal and usually takes place simultaneously in all the three cells (Fig. 6), although this is occasionally wanting in the chalazal chamber. The fourth division is also longitudinal but this is restricted to the middle and the micropylar cells. Thus, normally, we have at this stage two chalazal cells, four middle ones and four at the micropylar end. The middle tier undergoes further transverse and longitudinal divisions resulting in a well-developed endosperm tissue (Fig. 7), resembling the condition in *Sopubia*, *Alonsoa* and other members already described by the author (1937).



Vandellia hirsuta Ham. Fig. 1. L. S. of the ovary to show the orientation of the ovules (× 94). Fig. 2. L. S. of the ovule showing the embryo-sac with its extra-micropylar part in contact with the tapetal and funicular epidermis (× 960). Fig. 3. A stage in the fertilization of the egg-cell (× 2190). Fig. 4. The secondary nucleus and the sperm nucleus in close proximity (× 960). Fig. 5. First division of the endosperm nucleus completed (× 960). Fig. 6. The organisation of the micropylar, chalazal and endosperm tiers (× 640).

The fully formed endosperm tissue is differentiated into three regions of which the middle consists of large starchy cells. Towards

its upper as well as lower side there are smaller cells poorer in starch but richer in protoplasm. These connect the endosperm proper with the haustoria and probably assist in the transportation of food from the latter to the more deeply placed endosperm tissue.

ENDOSPERM HAUSTORIA.—The two chalazal cells enlarge to a certain extent and press against the antipodals which begin to collapse. Since the separating membrane between the two cells is very thin it frequently dissolves away resulting in the formation of a single bi-nucleate haustorium as seen in Fig. 8. One of the nuclei lying in the tapering lower end of the haustorium shows a marked tendency to degenerate, while the other enlarges considerably (Fig. 9). At times even the vestiges of the degenerating nucleus cannot be made out. Some of the sections examined by me failed to show any nuclear division in the chalazal chamber, which may thus be uni-nucleate from the beginning. These facts indicate a tendency towards the establishment of a uni-nucleate haustorium which happens to be a constant feature in *Limnophila*, *Stemodia* and other allied forms. I am unable to explain with certainty why one of the two nuclei should degenerate, but it seems to be a way for re-establishing the uni-nucleate condition.

A noteworthy feature of the chalazal haustorium is the occurrence of several cellulose rods protruding into it from the periphery (Fig. 9). It is also noticed that older haustoria, which become reduced in size, are wanting in these bodies. Schmid (1906) who has also seen these attributes a mechanical role to them, but their disappearance in later stages makes it seem equally likely that they have a nutritive function of some kind.

The micropylar tier develops into the four long vermiform haustorial arms (Fig. 6), which later fuse together to form a single tetra-nucleate body similar to the one met with in the previously described plants. Its protoplasm is highly vacuolated and several large granular bodies are included in it. Similar bodies are also met with even in the chalazal haustorium. The nuclei enlarge, become amæboid and strongly chromatic during older stages.

As mentioned before the outer part of the sac begins to shrink inwards (Figs. 8 and 9) and its contents are drawn into the micropyle making the protoplasm denser in this region. Since the contact between the sac and the placenta is now broken (Fig. 9), it is no longer possible for the former to draw nourishment directly from the placenta and the funicle. The resources of the micropylar haustorium are now limited only to the integument. Since it does not show any appreciable enlargement it is highly doubtful if it could absorb an adequate quantity of nutrition for the growing endosperm and embryo. To add to the difficulty the chalazal haustorium also shows senility at this stage. Unlike *Utricularia* in which the absorptive activity of the extra-micropylar part of the embryo-sac goes on quite vigorously even during post-fertilisation stages of development, this plant appears to be in need of some other structures to aid in the nutritional physiology of the sac.

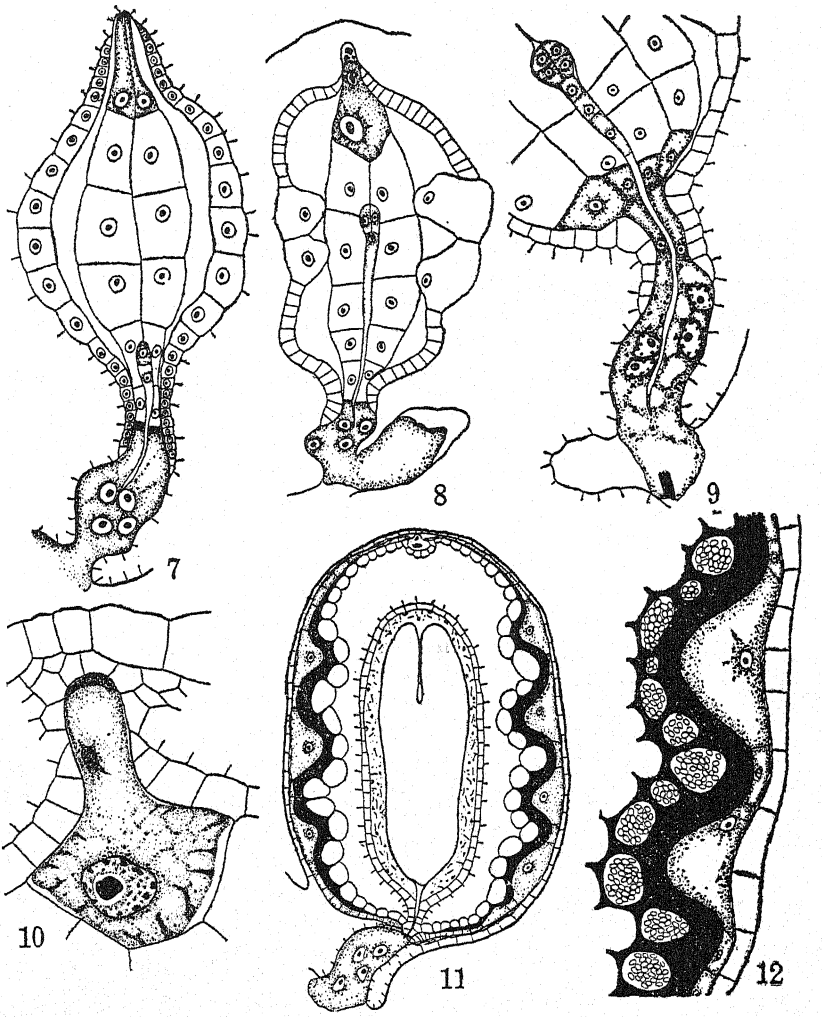


Fig. 7. The tetra-nucleate micropylar haustorium and the 2-celled chalazal tier with endosperm cells between (× 640). Fig. 8. Bi-nucleate chalazal haustorium with one nucleus degenerating and 4-nucleate micropylar haustorium. Note the enlargement of some of the tapetal cells (× 525). Fig. 9. Micropylar haustorium and the embryo (× 640). Fig. 10. Chalazal haustorium showing one degenerating nucleus, a hypertrophied amœboid nucleus and cellulose rods (× 1460). Fig. 11. L. S. of nearly mature seed showing the tapetum, endosperm, embryo and the haustoria (× 235). Fig. 12. Part of the tapetum and endosperm enlarged (× 640).

INTEGUMENTARY TAPETUM.—Just at the time when the chalazal haustorium shows signs of senility, the tapetum becomes highly

active. Some of its cells show a significant increase in size and bulge towards the endosperm (Fig. 8). A similar condition has been reported by the author (1939*a*) in *Celsia*. Some of these cells are at times even larger than the haustoria. Their number and position seem to depend on the needs of the growing endosperm and the nutritional regions. The digestion and absorption of the integumentary tissues appear to be quite rapid after the organisation of these special cells, and this process is so thorough that there is practically no tissue left between the tapetum and the integument (Figs. 11 and 12). The radial walls and the outer tangential walls of the tapetum remain thin for a long time, but the inner tangential walls become conspicuously thickened. Digestion and absorption of the integumentary tissue are made possible by the unthickened nature of the outer tangential walls. The large size of the cells and their rich contents indicate not only haustorial activity, but also a storage function. Towards the two ends of the embryo-sac even the inner tangential walls of the tapetal cells are thin. These two channels facilitate the translocation of food substances towards the inside. During pre-fertilisation stages of the embryo-sac the tapetum happens to be only a repository for food materials. On account of the peculiar needs of this plant it has to perform two functions: firstly, the digestion and absorption of food from the outer tissues, and secondly its storage and transportation. A third function is that of protection which is again of no little importance, since the epidermis of the seed-coat is unthickened and there is no other layer of cells left between it and the tapetum.

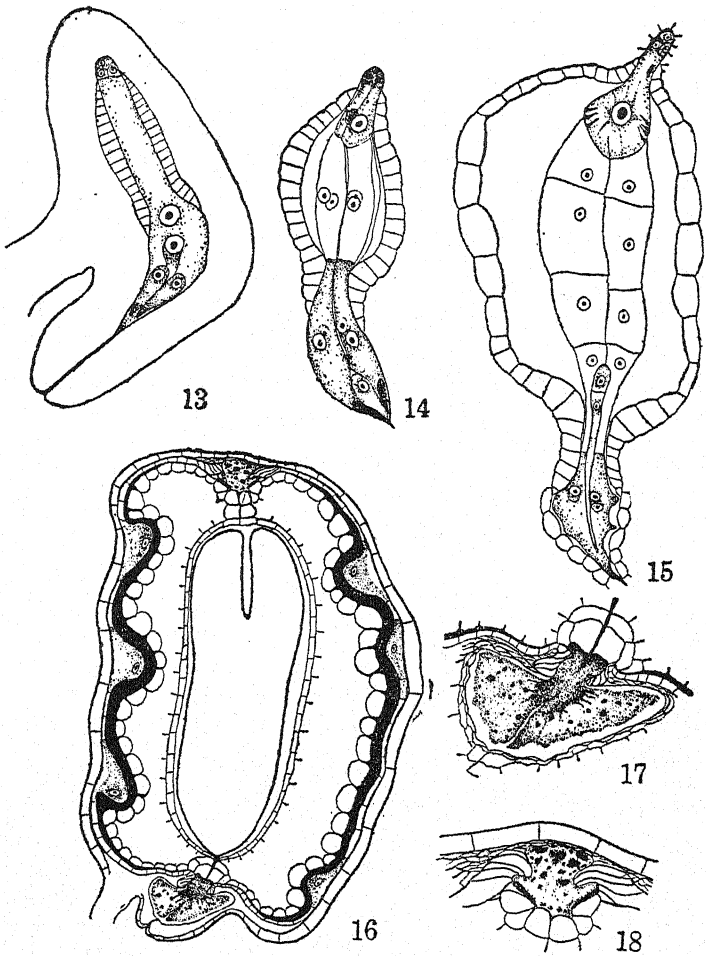
Vandellia scabra Benth.

The ovules are attached to the placenta, the cells of which are rich in starch. The differentiation of the placental tissue, so characteristic of *V. hirsuta*, is not met with here.

EMBRYO-SAC.—The micropylar part of the embryo-sac (Fig. 13) is enlarged and contains the egg-apparatus. The synergids are well developed and their upper ends are long and tapering towards the micropyle. The integument is drawn out into a long beak-like structure as seen in Fig. 13. As regards the position of tapetum and the nature of the antipodals the two species are closely similar.

EMBRYO AND ENDOSPERM.—The account given for *V. hirsuta* holds good here also. There is no difference even as regards the succession of the divisional stages.

ENDOSPERM HAUSTORIA.—Just as in the first species a tetra-nucleate micropylar haustorium develops from four uni-nucleate cells (Figs. 14 and 15). The frequent occurrence of a uni-nucleate chalazal haustorium without even a vestige of the second nucleus is also similar. The cellulose rods in the older chalazal haustoria of this species are confined to the sides of the dilated part instead of being uniformly distributed (Figs. 15 and 16). The disintegration of the nuclei of the older haustoria is more conspicuous in this species than in *V. hirsuta* (Figs. 16 and 17).



Vandellia scabra Benth. Fig. 13. L. S. of the ovule showing the integument, tapetum and the embryo-sac (× 640). Fig. 14. Differentiation of the chalazal and micropylar haustoria and endosperm cells (× 640). Fig. 15. Diagram showing the antipodals, the formation of the tetranucleate micropylar haustorium, bi-nucleate chalazal haustorium with one of the nuclei degenerating, embryo and endosperm (× 640). Fig. 16. L.S. of an almost mature seed showing the degenerating haustoria and well-formed tapetum (× 320). Fig. 17. Older micropylar haustoria with the disintegrating nuclei (× 730). Fig. 18. An old chalazal haustorium (× 730).

TAPETUM.—The tapetum is slightly different from that of *V. hirsuta* inasmuch as the upper end is composed of larger cells forming a collar-like structure. The formation of large tapetal cells irregularly scattered along the sheath and having a digestive, absorptive and storage function, and the peculiar thickening of the

walls of tapetal layer to facilitate translocation and combine with it efficient mechanical function are similar in both the species.

Summary

1. In *Vandellia hirsuta* the placental region is differentiated into an epidermis composed of richly protoplasmic cells, and an inner tissue of starchy cells some of which scattered here and there are much larger than the others. Such a differentiation is wanting in *V. scabra.*

2. In *V. hirsuta* the embryo-sac protrudes out of the micropyle and its dilated upper end comes in direct contact with the placenta and the funicle. In *V. scabra* this feature is lacking.

3. The development of the embryo-sac is quite normal in both the species, and the integumentary tapetum lines the non-dilated lower part of the embryo-sac.

4. In both the species the chalazal haustorium is laid down before the micropylar.

5. The chalazal chamber usually divides longitudinally into two uni-nucleate cells, but the thin separating membrane has a tendency to disappear very early resulting in a single bi-nucleate haustorium. One of the two nuclei often undergoes an early degeneration.

6. At times the chalazal chamber does not divide at all, but develops directly into a single uni-nucleate haustorium. This indicates a clear tendency towards the formation of a uni-nucleate chalazal haustorium.

7. The four micropylar haustoria fuse to form a single non-aggressive tetra-nucleate body.

8. Here and there some cells in the integumentary tapetum become highly enlarged and these probably take part in the digestion, absorption and storage of the tissue contents of the integument. The protective role of the tapetum by a thickening of its walls is also common to both the species.

My sincere thanks are due to Dr. M. A. Sampathkumaran, M.A., Ph.D., S.M. (Chicago), Professor of Botany, Central College, Bangalore, who was kind enough to provide facilities for this investigation, and to Dr. P. Maheshwari, D.Sc., F.N.I., of Dacca, whose suggestions and criticism were of invaluable help in writing this paper.

REFERENCES

1. Glišić, Lj. M. (1933) .. "Zur Entwicklungsgeschichte von *Gratiola officinalis* L.," *Bull. Inst. Jard. Bot. Univ., Beograd,* **2,** 129–52.

2. ———— (1936–37) "Ein Versuch der Verwertung der Endospermmerkmale fur typologische und phylogenetische Zwecke innerhalb der Scrophulariaceen," *Ibid.,* **4,** 42–73.

3. Junell, S. (1934) .. "Zur Gynäceummorphologie und Systematik der Verbenaceen und Labiateen," *Symb. Bot. Upps.*, **4**, 140–44.

4. Kausik, S. B. (1938) .. "Pollen development and seed formation in *Utricularia cœrulea* L.," *Beih. Bot. Cbl.*, **58**, 365–78.

5. Krishna Iyengar, C. V. (1937) "Development of the embryo-sac and endosperm haustoria in some members of Scrophularineæ—I. *Sopubia delphinifolia* and *Alonsoa* sp.," *Jour. Ind. Bot. Soc.*, **16**, 99–109.

6. ———— (1939 *a*) "Development of the embryo-sac and endosperm haustoria in some members of Scrophularineæ—II. *Isoplexis canariensis* and *Celsia coromandeliana*," *Ibid.*, **18**, 13–20.

7. ———— (1939 *b*) "Development of the embryo-sac and endosperm haustoria in some members of Scrophularineæ—III. *Limnophila heterophylla* and *Stemodia viscosa*," *Ibid.*, **18**, 35–42.

8. Mauritzon, J. (1935) .. "Etwas über die Embryologie der Bignoniaceen," *Bot. Notiser* (*Lund.*), 60–77.

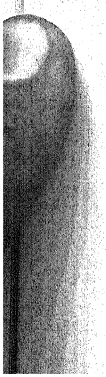
9. Millsaps, V. (1936) .. "The structure and development of the seed of *Paulownia tomentosa*," *Jour. Elisha Mitchell Sci. Soc.*, **53**, 56–75.

10. Schertz, F. M. (1919) .. "Early development of the floral organs and embryo-sac structures of *Scrophularia marylandica*," *Bot. Gaz.*, **68**, 441–50.

11. Schmid, E. (1906) .. "Beiträge zur Entwiclungsgeschichte der Scrophulariaceen," *Beih. Bot. Cbl.*, **201**, 175–299.

12. Svensson, H. G. (1928) "Zur Entwicklungsgeschichte der Blüten und Samen von *Limosella aquatica* L.," *Svensk. Bot. Tidskr.*, **22**, 465–76.

13. Wylie, R. B., and Yocom, A. E. (1923) "Endosperm of *Utricularia*," *Univ. Iowa Studies in Nat. Hist.*, **10**, 3–18.



ON THE FORMATION OF GAMETES IN *CAULERPA*

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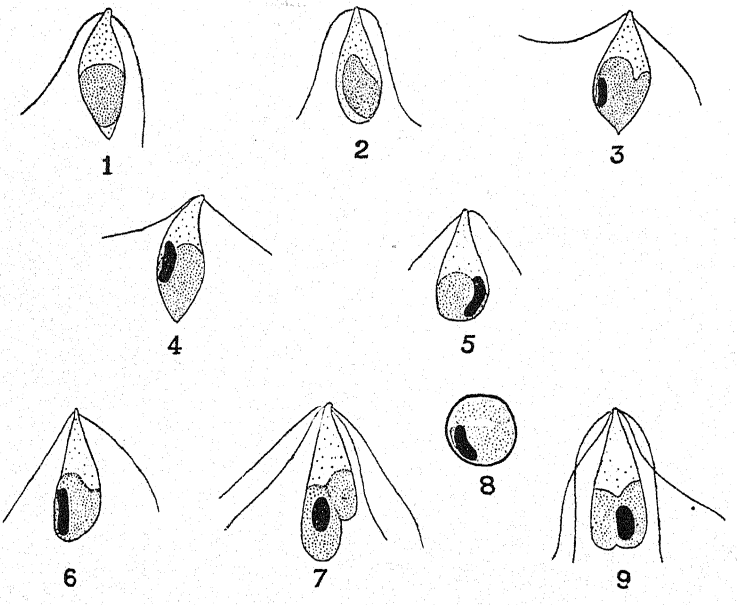
Received for publication on 7th January 1940

UNTIL very recently the only method of reproduction known in *Caulerpa* was by vegetative reproduction. Dostal[1] in 1928 observed elongated papillæ on the assimilators of *Caulerpa prolifera*. Later on in 1929 he[2] observed the contents of the assimilators in this *Caulerpa* issuing out as a mass of mucilaginous matter containing a large number of biciliate swarmers. In the same year Schussnig[7] also observed the phenomenon in the same species. But they were not able to decide whether the swarmers were zoospores or gametes. Since then a few other authors also have observed the phenomenon in some other species. In 1932 Ernst[4] found in *Caulerpa clavifera* and some other species biciliated swarmers of two sizes. Since the swarmers were of two different sizes, he concluded that they were gametes and that their conjugation would be anisogamous. He found these two types of swarmers in different plants and so suggested that the plants were dicœcious. But actual conjugation of the gametes was not observed by him. The writer, in 1933, observed at Krushadi Island near Pamban in South India, the formation of biciliate swarmers in *Caulerpa racemosa* var. *uvifera* Weber von Bosse. These swarmers were of two sizes, and as suggested earlier by Ernst, proved to be gametes and were conjugating anisogamously. A preliminary account of the writer's observations was published by him[5] in the same year. In 1937 Miyake and Kunieda[6] observed the formation of gametes in *Caulerpa brachypus* in Japan. They found that the conjugation was anisogamous. These two authors evidently were not aware of the writer's earlier record[5] of the conjugation of the gametes in *Caulerpa* and so have not referred to it in their paper. The details of their observation regarding the gametes and the conjugation, however, agree very well with those of the writer.

In the preliminary note published by the writer in 1933[5] only the occurrence of the gametes and their conjugation in the *Caulerpa* was recorded. The publication of the details of the writer's observations was postponed with the idea of amplifying them by further observations on more species in the locality. He therefore visited the island on three different occasions after that and examined a large number of specimens of different species of *Caulerpa* to find out if any gametes were being formed, but without success. He sees no point in delaying the publication of his original observations and drawings any further and so gives them here below.

The assimilators in a few specimens of *Caulerpa racemosa* var. *uvifera* Weber von Bosse showed a reticulate appearance caused by the accumulation of the protoplasm in a net-like manner inside. The colour of these assimilators with the net-like appearance was slightly yellowish-green. The specimens were kept in fresh sea-water in a glass vessel and watched for a long time for the formation of the papillæ on the surface of the assimilators and for the escape of the contents as motile spores. Though they were watched for a long time, the formation of the papillæ and the escape of any motile spores were not seen. The contents of some of these assimilators, when examined, showed a large number of rounded green bodies exhibiting a slight movement inside. A careful examination under higher magnification showed a large number of spores actively moving inside. As the writer's stay on the island had to be very brief, he could not wait and follow the development of the papillæ and the escape of the swarm spores. Portions of these assimilators were therefore cut and placed in fresh sea-water in glass vessels. Immediately, the contents of the assimilators slowly escaped from the cut end as a thick brownish-green viscous liquid and settled at the bottom of the water in the dish. A drop of this dark liquid, when mounted on a slide and examined under the microscope, showed a large number of biciliate swarmers actively moving in it. These after a short time began to fuse with each other in pairs. The



TEXT-FIGS. 1–9. Gametes of *Caulerpa racemosa* var. *uvifera*

Figs. 1–6. Gametes showing various shapes. Figs. 7 & 9. Anisogamous conjugation. Fig. 8. Zygote. (All Figs. × 2150.)

conjugation was anisogamous, one of the gametes being larger than the other. The gametes were spindle-shaped to pear-shaped with the posterior end either rounded or pointed. The eyespot is somewhat median in the spindle-shaped ones (Text-figs. 3 and 4) and more towards the posterior end in the pear-shaped ones (Text-figs. 5 and 6). The two cilia are slightly longer than the body of the gamete. A small papilla is seen at the anterior end. Of the two conjugating gametes, only the female gamete possesses an eyespot while the male does not show it (Text-figs. 7 and 9). The female gamete measures 2·6–2·9 μ broad and 7·0–8·25 μ long and the male gamete 2·3–2·6 μ broad and 6·5–7·6 μ long. After conjugation the zygote loses its cilia and becomes round and covers itself with a wall (Text-fig. 8). The further development of the zygote could not be followed.

Schussnig[8] in a recent paper has given an account of the cytology of the swarmer formation in *Caulerpa prolifera*. He found reduction division taking place during the formation of the swarmers and concludes that the plants are diploid and the swarmers haploid. It is very probable that the plants in *C. clavifera* and in *C. racemosa* var. *uvifera* are also diploid and that reduction takes place during gamete formation. From the fact that Ernst[4] found gametes of two sizes in different individuals in *C. clavifera* and other species and Iyengar[5] observed anisogamous conjugation in *C. racemosa* var. *uvifera*, Schussnig[8] assumes that the plants (diploid) in *Caulerpa prolifera* are of two kinds, one kind forming male gametes and the other female gametes, reduction division taking place in each kind just before gamete formation. He therefore considers that *Caulerpa prolifera* is diploid dicœcious. But it must be mentioned here that in the present alga (*C. racemosa* var. *uvifera*) the conjugating gametes were found in the liquid which oozed out of the cut end of a branch of a single plant. This shows that the plant is not dicœcious but monœcious and further that the conjugation takes place between the gametes formed by the same individual. *C. racemosa* var. *uvifera* is therefore monœcious while *C. clavifera* and the other species studied by Ernst[4] are dicœcious. Schussnig[8] assumes that the plants in *C. prolifera* are diploid dicœcious. They are diploid alright. But whether they are really dicœcious or monœcious can be decided only after observing the gamete formation in the alga, since the plant in one of the species of the genus, *viz.*, *C. racemosa* var. *uvifera*, appears to be definitely monœcious.

LITERATURE CITED

1. Dostal, R. (1928) .. " Zur Frage der Fortpflanzungsorgane der Caulerpaceen," *Planta*, **5**, 622–34. [From *Bot. Centralbl.*, N.F. Bd. **14**, (Bd. **156**), 297.]

2. ———— (1928) .. " Sur les organes reproducteurs de *Caulerpa prolifera*," *C. R. Acad. Sci.*, Paris, **187**, 569–70.

3. Dostal, R. (1929) .. " Uber Holokarpie bei den Caulerpaceen," *Planta*, **8**, 84-139. [From *Bot. Centralbl.*, N.F. **16**, (158), 169.]

4. Ernst, A. (1931) .. " Untersuchungen an tropischen Caulerpen", (Vorl. Mitt.), *Planta* **15**, 459-94. [From *Bot. Centralbl.*, 1932, N.F. **21** (163), 428.]

5. Iyengar, M. O. P. (1933) " On the formation of gametes in a *Caulerpa*, (Preliminary Note)" *Journ. Ind. Bot. Soc.*, **12**, 235.

6. Miyake, K. and Kunieda, H. (1937) " On the sexual reproduction of *Caulerpa*, (Preliminary Note)," *Cytologia*, **8**, 205-07.

7. Schussnig, B. (1929) .. " Die Fortpflanzung von *Caulerpa prolifera*", *Oesterr. Bot. Zeitschr.*, **78**, 1-8.

8. ———— (1939) .. " Ein Beitrag zur Entwicklungsgeschichte von *Caulerpa prolifera*," *Botaniska Notiser*, 75-96.

ON SEXUAL REPRODUCTION IN A *DICTYOSPHAERIUM**

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AN alga which appears to be a new species of *Dictyosphœrium* (*D. indicum* sp. nov.) occurs in large quantities as plankton in some small muddy rain-water pools near Madras. The cells of the alga, when young, are elliptic, spindle-shaped and somewhat flat on one side and slightly convex on the other (Text-figs. 1, 3). Each cell has a parietal plate-like chloroplast with a single pyrenoid embedded in it. The chloroplast in the young cell is placed at its centre close to its convex side (Text-fig. 3). The single nucleus is situated very near the pyrenoid. As the cells grow older, they become more and more swollen and assume finally a broadly elliptic shape (Text-figs. 1, 2, 5). These older cells contain generally two chloroplasts, one at either end of the cell, each with a single pyrenoid (Text-figs. 1, 2), the two chloroplasts being derived through the division of the single chloroplast of the younger cell. These enlarged older cells contain, however, only a single nucleus.

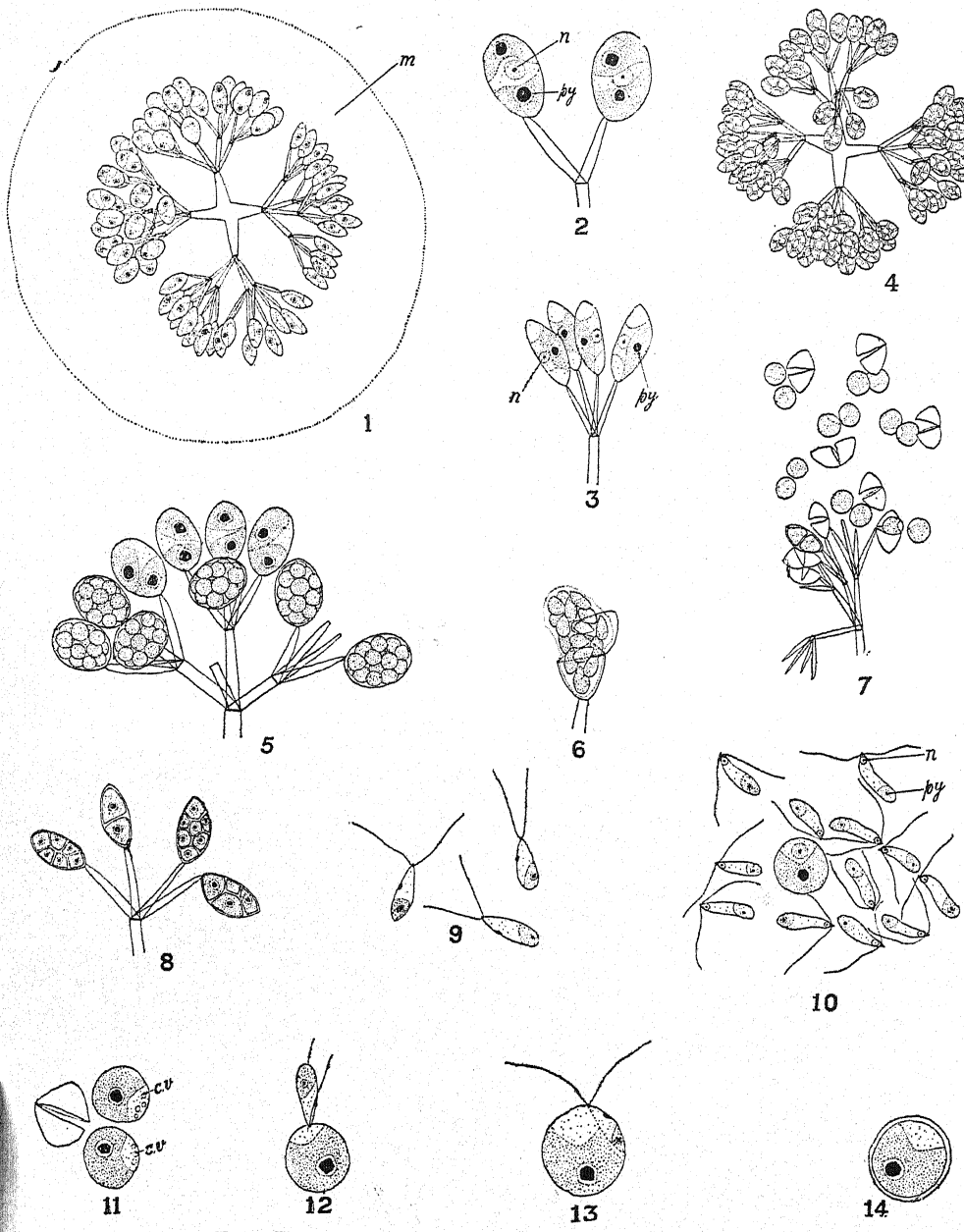
VEGETATIVE REPRODUCTION

Vegetative multiplication takes place by autospore formation. The contents of each cell divide into two or four protoplasts, each one of which surrounds itself with a wall. The mother-cell wall splits open into four quartets, the split commencing at the top of the cell and running downwards along its length. The daughter cells after the rupture of the mother cell remain attached by their one end to the tip of each lobe of the mother-wall. By such repeated autospore formations, colonies with a large number of cells are formed with the cells arranged near the periphery, the ruptured mother-walls of the previous generations forming a radiating system at the centre (Pl. I, Fig. 1, Text-figs. 1, 4). The entire colony is embedded in a wide gelatinous matrix (Text-fig. 1 *m*).

SEXUAL REPRODUCTION

The colonies of the alga are found mostly in a vegetative condition. Very occasionally, especially towards the end of the vegetative period, the colonies begin to show sexual reproduction. The colonies are dicœcious, some producing biciliate antherozoids and

* From the Department of Botany, University of Madras, Madras.



TEXT-FIGS. 1–14. *Dictyosphœrium indicum* sp. nov.

Fig. 1. Vegetative colony with the mucilaginous envelope (× 307).
Fig. 2. Two fully mature cells showing two chloroplasts and a single

others non-motile eggs. Both the male and the female colonies, however, are quite similar to one another in external appearance, until the formation of the gametes.

Male colonies.—In the male colonies almost all the cells divide to form antherozoids (Pl. I, Fig. 2 ; Text-fig. 4). The larger ellipsoidal cells generally form 16 or 32 antherozoids (Text-fig. 5), while the smaller and younger cells form generally eight antherozoids (Text-fig. 8). The antherozoids when fully formed, are discharged outside in a mass (Text-fig. 6) enclosed in a delicate protoplasmic membrane, the discharge taking place by a transverse rupture of the mother-cell wall (Pl. I, Fig. 3 ; Text-fig. 6). Soon after their discharge the investing membrane dissolves away very rapidly and the antherozoids become free and swim away. They are elongate with a somewhat rounded posterior end and a narrow anterior portion, with a tiny beak at the end (Text-figs. 9, 10). They are 8·4–10·0 μ long and 3·34 μ broad and possess two cilia, which are nearly 1½ times as long as the length of the body. They have each a small parietal chloroplast at the posterior region and a somewhat streak-like eyespot towards the anterior end (Text-fig. 9). A small pyrenoid is seen embedded in the chloroplast.

Female colonies.—The contents of the cells of the female colony divide only once and form two eggs each (Pl. I, Figs. 4, 6 ; Text-figs. 7, 11). These eggs are discharged outside the cell through a transverse median rupture of the cell-wall (Text-figs. 7, 11) and remain inside the surrounding mucilage of the colony, not far from the ruptured mother-wall (Pl. I, Figs. 4, 5, 6 ; Text-figs. 7, 11). These egg-cells are rounded and do not possess a cell-wall. They contain each a single nucleus and a parietal plate-like chloroplast with a single pyrenoid in it (Text-figs. 10, 11). They are non-motile and do not possess any cilia or eyespot. They possess, however, 2–6 contractile vacuoles situated near the anterior hyaline region (Text-fig. 11, *c.v.*).

Fertilisation.—The antherozoids after their discharge from the male colonies, swim towards the female colonies and surround the

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nucleus (× 1070). Fig. 3. Four young cells each showing a single chloroplast and a single nucleus (× 1070). Fig. 4. A male colony showing the division of its cells to form antherozoids (× 307). Fig. 5. Portion of a male colony showing fully formed antheridial cells (× 707). Fig. 6. Discharge of the antherozoids from an antheridial cell ; note the delicate protoplasmic vesicle enclosing the antherozoid mass. (× 707). FIG. 7.—Portion of a female colony showing the pairs of discharged eggs from their mother cells (× 483). FIG. 8. Portion of a male colony showing the division of the younger cells to form antherozoids (× 707). Fig. 9. Antherozoids (drawn from material fumed with osmic vapour) (× 1070). Fig. 10. Antherozoids swarming round an egg (drawn from material stained in iodine) (× 1070). FIG. 11. Two eggs just discharged from their mother cell ; note the contractile vacuoles (*c.v.*) at their anterior ends (× 1070). Fig. 12. Antherozoid about to fuse with an egg. (× 1200). Fig. 13. Antherozoid just fused with an egg ; the two cilia of the antherozoid are seen still attached to the zygote. (× 1330). Fig. 14. A fully formed zygote with the wall surrounding it. (× 1330).

(*m.* mucilage ; *py.* pyrenoid ; *n.* nucleus , *c.v.* contractile vacuole.)

eggs in large numbers (Pl. I, Fig. 5 ; Text-fig. 10). By their active movement, the antherozoids often set the egg moving round and round, reminding one of the eggs of *Fucus*. Finally one of the antherozoids succeeds in getting attached to the egg near its anterior hyaline region and soon fuses with it (Pl. I, Fig. 7; Text-figs. 12, 13). During fusion, the antherozoid applies itself along its length to one side of the egg and gradually fuses with it (Text-fig. 13). After fusion, the two cilia of the antherozoid remain attached to the zygote, which then keeps moving round and round for a short time with the help of the two cilia of the male gamete (Text-fig. 13). Finally the cilia are lost and the zygote comes to rest and surrounds itself with a wall (Text-fig. 14). The eyespot of the male gamete remains clearly visible in the zygote for some time. The further fate of the zygote was not followed.

From the foregoing description it may be seen that the process of sexual reproduction in the alga is of a high type in being oogamous. The alga shows a further advance in being diœcious. Though numerous living sexual colonies were observed repeatedly on several days, no case was observed in which both the antheridia and the oogonia were formed in the same colony.

Discussion

The only method of reproduction known so far in *Dictyosphœrium* is by autospore formation. Massee (1891) and Zopf (1893) recorded the presence of biciliate swarmers in *D. Ehrenbergianum*, but their observations have not been confirmed so far and consequently the correctness of their record has been doubted by algologists [Printz, (1927), Smith (1933)]. Fritsch (1935) and Oltmanns (1922), however, say that the occurrence of swarmers is not improbable. But no case of sexual reproduction has been recorded so far in the genus. The present record of the occurrence of a highly advanced type of reproduction by means of motile biciliate antherozoids fusing with non-motile eggs is quite surprising in the genus. Until quite recently, no case of oogamous reproduction was known in the Chlorococcales. Korschikoff (1937) very recently, however, observed the occurrence of oogamous reproduction in the two genera *Golenkinia* and *Micractinium* belonging to this group. He found that in these two genera fertilisation took place by the fusion of biciliate antherozoids with non-motile eggs. The process of sexual reproduction in the present alga is very similar to that of the above-mentioned genera, except in a few details. In the present alga, two eggs are formed from each oogonium, whereas only one egg is formed in each oogonium in the two above-mentioned genera. Further, in the present alga, the eggs are discharged outside the oogonium before fertilisation, whereas in *Golenkinia* and *Micractinium* they are fertilised while still enclosed inside the oogonium. Finally, the antherozoids of *Micractinium pusillum* and *Golenkinia longispina* possess a wall which is not discarded until just before fertilisation, whereas, in the present alga, they are naked throughout from the

time they are set free. In this latter feature the present form agrees somewhat with *Golenkinia solitaria* Korschikoff, where the antherozoids are naked throughout. Finally, it may be mentioned that, when the sexual reproduction of such a high type as oogamy occurs in this genus, there appears to be no reason for doubting the occurrence of biciliated zoospores in *Dictyosphœrium Ehrenbergianum* as originally recorded by Massee (1891) and Zopf (1893).

The alga differs from the previously recorded species in the more or less plano-convex spindle-shaped nature of its younger cells and the enlarged elliptic shape of its older ones. Further it is distinguished from the other species by the occurrence of oogamous reproduction. It appears therefore to be a new species which may be named *D. indicum* sp. nov.

DESCRIPTION

Dictyosphœrium indicum sp. nov.

Colonies spherical to broadly ovoid or slightly irregular and consisting of 4, 16, 64 or more cells; cells elliptic, spindle-shaped and somewhat plano-convex when young and broadly elliptic when mature; younger cells 11·7–15·0 μ long and 5·0–8·4 μ broad, older cells 11·7–15·0 μ long and 8·4–10·0 μ broad; chloroplast single in young cells, two in older ones; parietal, plate-like, with a single pyrenoid; vegetative multiplication by the formation of 2–4 autospores in each cell; sexual reproduction by the fusion of a motile biciliate antherozoid with a non-motile egg; antherozoids spindle- to pear-shaped, 3·3 μ broad and 8·4–10·0 μ long; egg cells round, 8·4–10 μ in diameter; zygotes round and smooth-walled, 10·0–11·7 μ in diameter.

Habitat.—Planktonic in a muddy rain-water pool near Madras.

SUMMARY

An account is given in the paper of the life-history of a new species of *Dictyosphœrium* (*D. indicum*) from Madras. Sexual reproduction of an oogamous type was observed in the alga and has been described in detail. This appears to be the first record of sexual reproduction in the genus.

LITERATURE CITED

Fritsch, F. E., (1935) .. *The Structure and reproduction of Algæ*, Vol. I, Cambridge.

Korschikoff, A. A. (1937) .. On the sexual reproduction (oogamy) in the *Micractiniecæ*," *Proc. Kharkov A. Gorky State Univ.*, Book No. 10, pp. 109–126 (Russian with English summary).

Massee, G. (1891) .. " Life-history of a stipitate fresh water alga," *Journ. Linn. Soc. Lond. Bot.*, 27, 457–62.

Oltmanns, F. (1922) .. *Morphologie und Biologie der Algen.* 2nd Auf., Bd. 1, Jena.

Printz, H. (1927) .. " Chlorophyceæ", *in Die Naturlichen Pflanzen-familien*, 2nd Aufl., **Bd, 3.**

Smith, G. M. (1933) .. *The Fresh Water Algœ of the United States*, New York.

Zopf, W. (1893) .. " Über die eigentumlichen struktur-verhaltmisse und den Entwicklungsgang der *Dictyosphœrium* Kolonien," *Beitr. z. Physiol. Morph. nieder. Organ*, **Bd. 3,** 15-25 (cited after Oltmanns, 1922 and Printz, 1927).

EXPLANATION OF PLATE VIII

FIG. 1. Photomicrograph of a mature vegetative colony. × 412·5.

FIG. 2. A male colony, showing the division of the cell contents to form antherozoids. × 412·5.

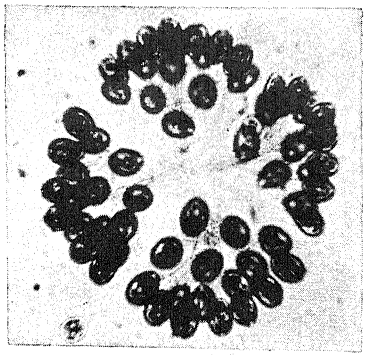
FIG. 3. A male colony showing the escape of the antherozoids ; antherozoids have already escaped from most of the cells of the colony. × 412·5.

FIG. 4. A female colony with pairs of eggs just discharged from their mother-cells, but still lying close to them inside the mucilage of the mother colony. × 412·5.

FIG. 5. Antherozoids actively swarming round the discharged eggs ; at the right hand top, a number of antherozoids can be seen swarming round a single egg. × 412·5.

FIG. 6. Two pairs of eggs just discharged from their mother cells and lying close to the ruptured mother-walls. ×675 .

FIG. 7. An antherozoid fusing with an egg ; two other free antherozoids are seen closeby. × 675.



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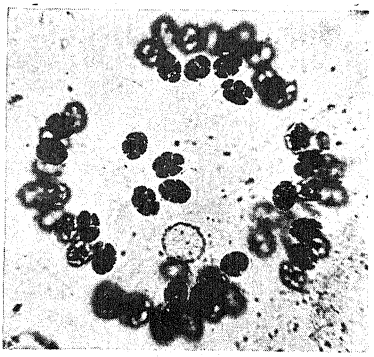

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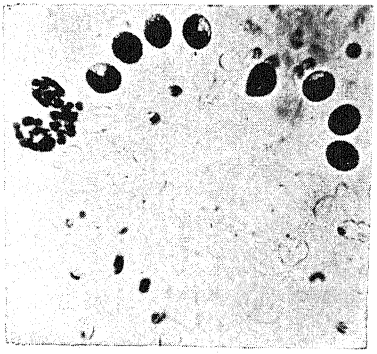

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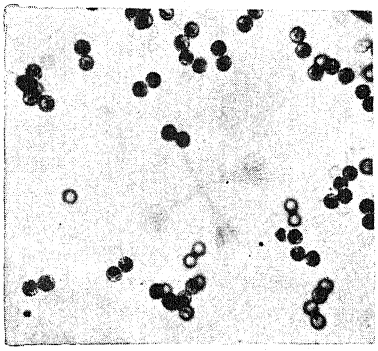

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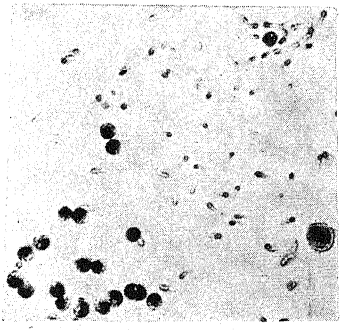

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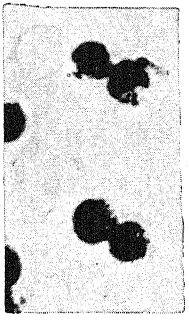

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M. O. P. IYENGAR
and
K. R. RAMANATHAN

DICTYOSPHAERIUM INDICUM

PALÆOBOTANY IN INDIA*

Progress Report for 1939

NOTE

SINCE the revival of palæobotanical research in India in 1921 the workers have multiplied in number and are now scattered over a large country. Hence the need has been felt for co-ordinating their activities by means of a committee and by the publication of an annual report. The outline map of India is intended to help the reader in locating the workers as well as the areas that have yielded the material reported upon.

The fossil floras that are at present engaging special attention are, in order of age, the *Glossopteris* flora (in the Salt Range and in the Bengal and Behar coalfields); the Jurassic (Upper Gondwana) flora of the Rajmahal Hills and of the Salt Range; the early Tertiary silicified flora of the Deccan, and the Pleistocene flora of Kashmir. Some work is also being done on material from other countries: Australia, Brazil, South Africa and Afghan-Turkistan.

We desire to thank our geological colleagues, particularly those of the Geological Survey, for their valued contributions of material and for much other assistance in the furtherance of our work.

The following papers contain references to all the previous literature on Indian fossil plants :—

(1922) .. "The present position of Indian palæobotany: Presid. Address, Botany Section," 8th Ind. Sci. Cong. Calcutta," *Proc. Asiat. Soc. Bengal, N.S.*, Vol. XVII, pp. clii–clxxv.

(1928–31) .. "Revisions of Indian fossil plants: Parts I and II—Coniferales," *Mem. Geol. Surv. Ind., Palæont. Indica, N.S.*, Vol. XI, pp. 1–124.

(1938) .. "Recent advances in Indian palæobotany: Presid. Address, Botany Section," *Proc. 25th Ind. Sci. Cong.* (Reprinted as *Lucknow University Studies*, No. II, pp. 1–100).

Department of Botany,
The University,
Lucknow,
January 29, 1940.

B. SAHNI,
Convener.
R. V. SITHOLEY,
Secretary.

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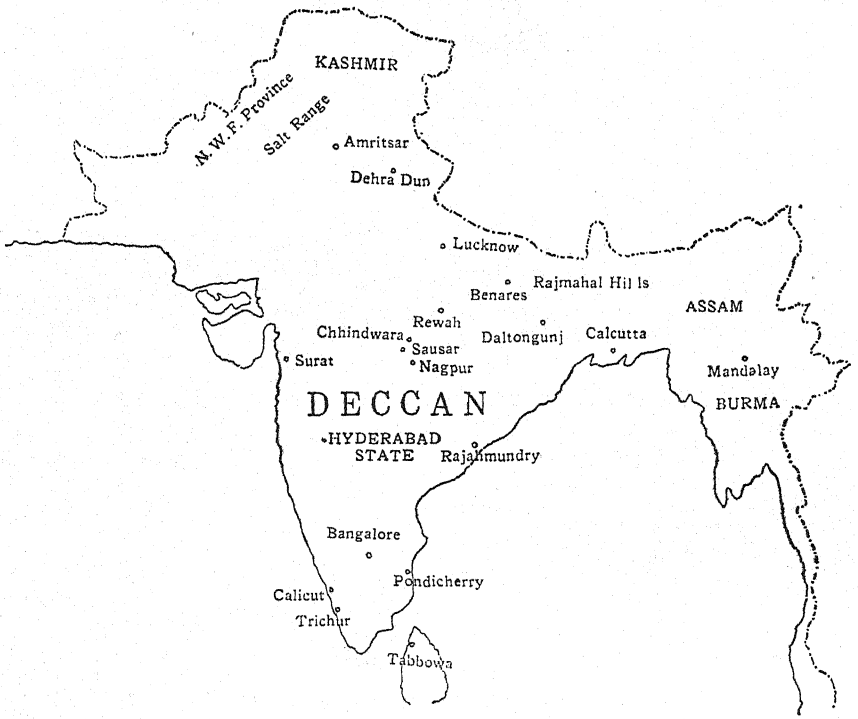
* This is a copy of a report issued in cyclostyle last January. Arrangements have now been made for publishing these annual reports through the medium of this *Journal*. It is hoped to issue the next report in the January number for 1941.



CARBONIFEROUS

Salt Range.—Miss C. Virkki is describing the flora of some of the earliest of the Gondwana sediments in the Salt Range, the horizons being as low as 1½ ft., 4½ ft. and 25 ft., above the Talchir (glacial) boulder bed. Associated with typical members of the *Glossopteris* flora, represented by leaf impressions of *Gangamopteris* and *Glossopteris*, a new species of *Ottokaria*, *Samaropsis* spp., *Cordaicarpus*, etc., she has found many different types of spores, winged and unwinged. The cuticles of several of the plants are being described and figured. The author hopes to pursue her study of spores and cuticles with a view to see if they can be used for a stratigraphical correlation of the lower Gondwanas and eventually of coal-seams in India.

This, the earliest of the known Indian Gondwana floras, has significance in connexion with the question of the climatic conditions in which the *Glossopteris* flora originated. The facts suggest that it was contemporaneous with the Talchir glaciation, spreading into the ice-free areas of Gondwanaland, but retreating as the ice advanced.

Victoria (*Australia*).—The above view is supported by the discovery by Miss Virkki, in a fragment of the tillite from Bacchus Marsh, Victoria, of several types of spores identical in structure with those found in the Lower Gondwanas of the Salt Range and in

the Daltongunj and Rewah basins. These spores must have belonged to early members of the *Glossopteris* flora. Flying about over the snow and ice the spores must have settled down on the surface and were ultimately entrapped and preserved in the moraines.

Tillites from several other parts of Gondwanaland are being searched for spores.

PERMO-CARBONIFEROUS

Daltongunj Coalfield (*Behar*).—The cuticle of *Glossopteris communis* has been described by Miss C. Virkki. In the same specimen of shale a number of free-lying spores were found.

New South Wales (*Australia*).—From a fragment of shale crowded with leaf incrustations of *Glossopteris browniana* Miss Virkki has recovered many double-winged spores of the *Pityosporites* type.

Rewah (*Central India*).—From a piece of *Glossopteris*-bearing shale Miss Virkki describes some spores similar to those found by her in the Salt Range Gondwanas and also in Behar and Victoria (see above).

PERMIAN

Brazil.—Specimens of *Lycopodiopsis Derbyi* obtained by Sahni on loan from the School of Mines, Paris, and from the Bonn Museum have been examined in detail by H. S. Rao. He confirms Renault's view that the stele consists of a ring of separate bundles, and that the genus is therefore distinct from *Lepidodendron*. Found in association with members of a *Glossopteris* flora, this species is regarded as a descendant of the southern pre-Gondwana lycopods, some of which are believed to have survived the Talchir glaciation.

TRIASSIC

Salt Range.—R. V. Sitholey (Lucknow) is describing a small flora collected by E. R. Gee in the Salt Range from beds regarded as Triassic. The plant remains are extremely fragmentary and their specific identification has not been so far possible. Isolated spores, some with a well-defined triradiate mark, have been obtained. Peel preparations have yielded cellular details in some fragments. The specimens consist of fragments mostly of the equisetaceous and sphenopteroid types; also isolated pinnule fragments with a *Cladophlebis* type of venation.

JURASSIC

Afghan-Turkistan.—A flora of undoubted Jurassic age, the only one yet collected from definitely recorded localities in Afghan-Turkistan, has been described by R. V. Sitholey. The material was collected by C. S. Fox. The collection includes, besides such characteristic Jurassic species as *Cladophlebis denticulata* and *Coniopteris hymenophylloides*, the following forms: *Sphenopteris*, *Nilssonia*, *Ctenis*, *Pagiophyllum*, *Mesembrioxylon*, *Podozamites*, etc. Of chief interest are some imperfectly preserved fronds which for

their pedate habit are remarkably like *Matonia*. A curious strobilus-like impression, *Strobilites* sp. nov., shows a number of obovate seed or fruit-like bodies attached spirally on an axis. (Expected publication in *Palæont. Indica*, Vol. XXIX, Mem. No. 1, pp. 1–26, Pls. 1–8.)

Rajmahal Hills.—K. Jacob (Lucknow) has completed a detailed investigation of the Jurassic flora of Sakrigalighat in North Behar. A new type of fructification, *Sakristrobus* gen. nov., is created for strobili with peltate sporophylls carrying numerous sac-like structures. A new species of *Sagenopteris*, *S. bhambhanii*, is described. The anatomical structure of the rachis of *Cladophlebis indica* and *Ptilophyllum acutifolium* and the epidermal features of *Tæniopteris* cf. *T. crassinervis* could be studied to some extent. Several other common Rajmahal forms are also described.

Jacob has also prepared a detailed account of the anatomy of a silicified fern, *Tinpaharia sinuosa* gen. and sp. nov., discovered by him at Tinpahar, on the loop line of the East Indian Railway in Behar. He gives reasons for the view that *Tinpaharia* represents the petrified vegetative organs of the widespread Jurassic fern *Coniopteris hymenophylloides*. The stems, petioles and roots have all been found organically attached together, while closely associated with them are seen leaf impressions, both sterile and fertile, strongly resembling those of *C. hymenophylloides*.

A. R. Rao (Lucknow) has completed two papers on some petrified plants from Nipania in the Amrapara District. The first paper gives a detailed account of the anatomy of *Tæniopteris spatulata*. The epidermal characters on the whole appear to suggest a Bennettitalean rather than a Cycadalean affinity, but the vascular bundles in the midrib (as already announced by Sahni) are exactly of the type seen in the modern cycads. The correct systematic position of the plant that bore these leaves can only be settled when the fructifications are known.

The second paper by the same author describes two silicified cones; a male cone, *Masculostrobus rajmahalensis* sp. nov., containing winged pollen grains of the abietineous or podocarp type, and associated with this cone several lax megastrobili characterised by scales bearing single sub-erect or inverted ovules with curved micropyles. Reasons are given for the belief that the male and female cones belonged to the same species, but pending a proof of this identity the female cones have been described under a new genus, *Nipaniostrobus*.

B. P. Srivastava (Surat), who died in December 1938, has left unpublished photographs and brief descriptions of several interesting new types of plants from Nipania. Preliminary papers were published by the author in *Proc. Ind. Sci. Cong.*, Calcutta, 1935, p. 285; *Ibid.*, Hyderabad (Deccan), 1937, pp. 273–74. It is hoped to publish the results as a posthumous work.

Salt Range.—Sahni and Sitholey are engaged in describing a large collection of Jurassic plants from the Salt Range made by

E. R. Gee of the Geological Survey of India. Numerous well-preserved cuticles have been prepared and it is hoped to reveal the internal anatomy of some of the mummified plants by means of microtome sections. Among the more important forms in the collection are (*a*) Ferns (sterile and fertile); a fragment, probably a *Laccopteris*, has yielded some finely preserved spores; (*b*) Forms of *Brachyphyllum* grading into *Pagiophyllum*; (*c*) Parallel veined leaves cf. *Podozamites* spp.; (*e*) lignites. Cuticular studies are expected to bring additional species to light.

Ceylon.—K. Jacob has completed the description of a small collection of Jurassic plants from Tabbowa in N. W. Ceylon. The following are the more interesting forms: *Coniopteris hymenophylloides*, *Cladophlebis* spp., *Anomozamites* (*? Nilssonia*) sp. and *Elatocladus plana*. The collection is of interest as it adds to our knowledge of this most southerly outpost of the Indian Gondwanas.

CRETACEOUS

Pondicherry.—The occurrence of fossil algæ in some of the limestones of this area was first noted by L. Rama Rao (Bangalore) about eight years ago. These fossils are now being examined in detail by L. R. Rao, S. R. N. Rao and K. S. Rao and the results are likely to throw some light on the exact age of the containing beds.

CRETACEOUS ? OR TERTIARY ?

Hyderabad.—K. S. Rao (Bangalore) is engaged in the study of the fossil flora of some of the intertrappean beds recently discovered near Gurmutkal, Gulbarga District, Hyderabad State. The material for study has been kindly lent by the Director, Department of Mines and Geological Survey, Hyderabad.

CRETACEOUS ? AND TERTIARY

Assam.—Some limestones of doubtful Cretaceous or Eocene age, together with other rocks which are definitely of Eocene age, sent by the Geological Survey of India for the investigation of their algal flora, are being studied by L. R. Rao and K. S. Rao (Bangalore).

TERTIARY

Deccan (*Intertrappean Beds*).—From the interbasaltic sedimentary beds of the Deccan a well-preserved silicified flora is being described by Sahni and co-workers. (See reports in Sahni, Srivastava and Rao, 1934, *Proc. Ind. Sci. Cong.*, Bombay, pp. 315–19; also Sahni and Rode, 1937, *Proc. Nat. Acad. Sci., India*, 7, 165–74, where other references are given.) A paper by B. Sahni and H. S. Rao, just completed, describes a collection made by the first author in 1926 in the region round Sausar in the Chhindwara district. This is a rather specialised flora, consisting largely of aquatic forms such as Charophyta, *Azolla intertrappea* sp. nov., and other water-ferns, including a possible *Regnellidium*, as well as various fragments of aerenchymatous tissues, presumably of aquatic angiosperms.

Several types of algæ, fungal mycelia with attached fructifications (including a new genus named *Palæosordaria* and a new species of *Perisporiacites*) and isolated spores of various kinds have been figured.

V. B. Shukla (Nagpur) has described the anatomy of *Palmoxylon kamalam* Rode from specimens collected in the Pupuldoh reserve forest area in the Central Provinces. He has also described a new species of *Dadoxylon*, *D. deccanensis*. Further material of petrified palms and dicotyledons has been collected near Nawargaon, Wardha District.

B. Sahni (Lucknow) began in 1920 a comprehensive investigation of Indian petrified palms (form genus *Palmoxylon*). So far as known, nearly all this material is of Tertiary age, and most of it comes from the Deccan Intertrappean series. Several brief notes were published as more and more material came to hand. The material has now grown so large that the work will be published as a joint investigation with the assistance of Mr. K. N. Kaul, Research Assistant. For interim reports on this work see Sahni, 1931, "Materials for a monograph of the Indian petrified palms," (with distribution map and 25 figs.) and references cited therein.

Rajahmundry.—A detailed study of the fossil Charophyta from the Intertrappean beds of this area by K. S. Rao and S. R. N. Rao (Bangalore) has been completed and will shortly appear as a memoir in the *Palæontologia Indica* of the Geological Survey of India (Vol. 29, Memoir 2—In press). Further studies in the fossil algæ from these beds are under progress ; the genus *Halimeda* and a new species of *Dissocladella* have been noticed.

North-West Frontier Province.—S. R. N. Rao (Bangalore) is studying the algal flora from the Lockhart limestone of the Ranikot succession in the Samana Range—the material having been presented to him by Lt.-Col. L. M. Davies. The occurrence of *Lithophyllum* has been noticed here for the first time.

Salt Range.—L. R. Rao and K. S. Rao (Bangalore) have recently discovered fossil algæ in the Eocene limestones of the Salt Range. A preliminary note concerning the find has just been published (*Curr. Sci.* November 1939, VIII, No. 11, pp. 512–13). The outstanding feature of this algal flora is the remarkable association of forms like *Dissocladella*, *Acicularia* and *Neomeris* which are known to commonly occur in Eocene beds, with others like *Diplopora* and *Oligoporella* which are elsewhere unknown in beds younger than the Triassic. A detailed study which is under progress promises to be of great interest, both from the stratigraphical and palæobotanical points of view.

Assam.—K. A. Chowdhury (Dehra Dun) has described two fossil dicotyledonous woods from the Garo Hills, Assam, under the name *Dipterocarpoxylon garoense* sp. nov. and *Dryoxylon* sp. (*Rec. G.S.I.*, Vol. 73, Pt. 2, pp. 247–66).

K. A. Chowdhury and S. Ghosh (Dehra Dun) are preparing a detailed account of a fossil wood, *Cynometroxylon indicum* gen. and

sp. nov., from Nailalung on the Assam-Bengal Railway. (For preliminary report see *Proc. 26th Ind. Sci. Cong.*, Lahore, 1939.)

Kashmir.—The best known Pleistocene flora of India is that of the Karewas of Kashmir, first collected by Godwin-Austen and later by Middlemiss, Wadia, deTerra, Sahni, Stewart and Puri. The best and largest collection, presented to Lucknow University by deTerra, has been lent for description to G. S. Puri (Amritsar). Only the macroscopic remains have yet been dealt with. Among the genera recognised by the late Dr. S. K. Mukerji and now confirmed by Puri, are *Quercus*, *Salix*, *Populus*, *Alnus*, *Berberis*, *Rosa*, *Trapa* and many others. Over 90 species belonging to 48 genera and 24 families have been determined, nearly all being modern forms living in the valley and neighbouring mountains of Kashmir.

S. C. Varma (Mandalay) is investigating the microflora of the Karewa beds, collected by Sahni from several localities: Gulmarg, Bota Pathri, Dangarpur, Hajabal, Satar Siran, etc., all in the Pir Panjal Range. The following genera have been identified by their pollen grains: *Pinus*, *Cedrus*, *Picea*, *Abies*, *Carpinus*, *Alnus*, *Betula*. Several other forms are still unidentified, the work being handicapped by a lack of knowledge of the modern pollens of Kashmir, which are now being collected.

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SUGARCANE x BAMBOO HYBRIDS

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I. Introduction

The present study was undertaken with two objects in view: to make certain if the hybrids were genuine crosses between the Bamboo and the Sugarcane and secondly, to derermine which of the characters were inherited from either parent and the nature of such inheritance.

Though considerable work has been recorded on the study and inheritance of the external morpholcgical characters of various hybrids, their anatomical characters have received comparatively little attention in the past. This is apparently because of such work being somewhat more difficult and time consuming.

II. Literature

Even before 1900 the problem of the inheritance of anatomical characters was tackled by Brandza (1890) in the hybrids between *Aesculus rubicunda* and *Pavia flava*. The hybrids in this case were found to resemble the former parent in the vascular structure of the petiole and the latter in the arrangment of vessels and grouping of phlœm cells. Based on the study of various hybrids he concluded that the hybrids resembled either one parent more than the other or exhibited intermediate characters.

It was found by Charlesworth and Ramsbottom (1916–17) that hybrid orchids showed intermediate characters with regard to the structure of the cuticle, epidermis, mesophyll, sclerenchyma, and vascular bundles. Miss Russel (1919) in the Sarracenia hybrids, and Funaoka (1925) in the hybrid between *Mirabilis jalapa* and *M. longiflora* found that the characters inherited are mostly intermediate between those of the parents. Williams (1923) found in hybrid vines some characters intermediate between the parents. But Beck (1921) found in the hybrids between Mahonia and Berberis that, whereas some characters as the cell wall thickening, number of cortical cells, and wood fibres were intermediate between the parents, other characters such as spines, the pitting, the size and thickness of bundles were similar to the Berberis parent, and characters such as the cell wall and cortical parenchyma resembled the Mahonia parent. Brown (1913) also found that the hybrid structure in *Nicotiana*, *Raphanus* and *Brassica* showed characters intermediate between the parents. Neilson Jones and M. C. Reyner (1915–16) have concluded that in hybrids such as *Bryonia dtoica*

which is the cross between two varieties with a number of vascular bundles limited to ten in one case and fourteen in the other, the inheritance regarding the number of bundles clearly exemplify the Mendelian ratio for the number of bundles. Likewise in a hybrid Cycad obtained by Sophia Papadopoulos (1928) from a cross between *Ceratozamia mexicana* and a new species of *Zamia monticola*, it was seen that some of the characters were after one parent whereas some others as the stomata showed both the parental type.

Macfarlane (1892) working on hybrids between various plants came to the conclusion that most characters of the hybrids showed the combined effect of the traits of both the parents. He found that the characters of the parents are so harmoniously blended that the structure gave very little facilities for the determination of the effect of either the pollen or the seed parent on the offspring. He also observed the presence of certain traits, foreign to either of the parents. The root, for instance, though intermediate between the two parents, on the whole showed the cylinders similar to those of the seed parent in a few characters. Even in the chemical constituition of the cell wall and colour and odour of the flowers, inheritance showed an intermediate condition or a mixture of the two.

Sinnot, Hougtaliq and Blackslee (1934) in their comparative anatomy of the extra chromosomal type in *Datura stramonium* found clear differences between the diploids, triploids, tetraploids and other mutants. They say that in certain characters the hybrids resemble one parent and in certain others the other parent, but in all essential respects the hybrids were found to be intermediate. They observed that artificial hybrids inherit more the characters of the female parent.

All the above investigators hold that the anatomical characters are inherited and that a certain amount of seggregation takes place. As their observations were confined mostly to the F_1 generation, no definite data as regards segregation of anatomical characters had been established.

III. Material and Methods

The material for this study was collected from the Imperial Sugarcane Breeding Station at Coimbatore, and includes three generations of hybrid plants growing in the field. This wide intergeneric hybridization was attempted with the definite object of introducing newer genes into sugarcane breeding. P.O.J. 213 was employed as mother parent as it is practically devoid of own fertile pollen and also because it was known to set seed very freely. The bamboo pollen was obtained from inflorescences collected the previous day from the neighbouring forests and brought to the station. Each morning the inflorescences were exposed in a closed room when it was found that the anthers soon protruded and liberated healthy pollen. Such collected pollen was used as soon as possible after the anther dehiscence. In the raising of the F_2 generation plants, the

inflorescences were not bagged as there was little chance of unintended pollen fertilizing them. In this particular batch the seedlings examined consisted of (1) eighteen plants of the F_1 generation. (2) about 300 plants of the F_2 generation obtained from different F_1 individuals, and (3) twelve seedlings obtained by back crossing two of the F_1s with bamboo.

The external morphological characters were studied mostly in the field by taking proper representative specimens. For the study of anatomical characters, the root, the stem, the leaf and the leaf-sheath were takein. Prevous work on Saccharum anatomy* had shown that for proper comparison only mature portions of the plant have to be taken and this was adopted in the present case. The sections were mostly cut with the hand, stained with iron alum-hæmotoxylin and safranin and subsequently mounted in canada balsam.

The characters of both the parents were studied and tabulated (Table I). A priliminary study of the hybrids showed that, as observed by previous workers, the characters of the mother were present to a very large extent in them. So the method adopted was to pick out, by comparison of the parents, such characters as could be definitely attributed to the father if found in the hybrids. The characters that could thus be picked out were fairly large in number. They are given in Table I, but when the hybrids were examined only a few of these characters were actually found in them. The attached statement (Table II) gives a list of the characters that were found in the hybrids and the frequency of their occurrence.

IV. Results

An analysis of the results as given in Table II brings out the undermentioned points:

(*a*) *External Morphology*

The shoot.—Three characters, *viz.*, (1) ascending root eyes (Pl. IX, Fig. 5), (2) buds bursting through the leaf-sheath and (3) the claw shape of the bud (Pl. IX, Fig. 3) occur most frequently in the hybrids. The first occurred in 100, the second in 98, and the third in 60, out of the 300 hybrids examined. The next most frequent character was multiple buds (Pl. IX, Fig. 1). A hard shiny surface was met with in a few. Two important bamboo characters are the spiral arrangement of the leaves (Pl. IX, Fig. 6) and the circlet of hairs at the leaf scars (Pl. IX, Fig. 4). Of these, the first occurred in only one of the F_1 hybrids and the second in three. The small size of the leaves and the presence of petiole were two definite bamboo characters not found in the hybrid shoots.

The inflorescence.—There is a great difference in the general appearance of the inflorescences of the two parents due to the number, arrangement and size of the spikelets and the branching of the

* Under Prof. Dr. T. Ekambram, Presidency College, Madras, and financed by the Imperial Council of Agricultural Research.

rachises. Among 75 of the F_2 hybrid inflorescences examined, 20 showed a leaning towards the bamboo type. The rest were of the

TABLE I

The Characters of the Two Parents

	Sugarcane (P.O.J. 213)	Bamboo
	External Morphology	
Stem ..	Internodes—purplish, short, soft and dull	Internodes—hard, green and shining
Buds ..	Single, small, close to the leaf-scar, straight and adpressed to the stem	Double or multiple, big, away from the leaf-scar and claw-shaped
Leaf-scar ..	Without hairs	With hairs
Leaf-sheath ..	Does not usually burst, open	Bursting closed
Root-eyes ..	Not ascending	Going above and round the bud
Leaves ..	Big, sessile, continuous with the sheath	Small, petioled
Ligular hairs ..	Unicellular	Multicellular
Inflorescence		
Rachises ..	Arranged in whorls, zigzag	Binate, straight
Spikelets ..	Two at each node ; one sessile and one pedicelled	Many arranged in whorls ; all sessile
Glumes ..	Non-hairy	Hairy
Palea ..	Single-keeled	Bi-keeled
Stamens ..	Three	Six
Lodicules ..	Two, fleshy and small	Three, fimbriate, thin and big
Stigmas ..	Two	Three
Root	*Anatomy*	
Pith ..	Small, composed of angular and parenchymatous cells	Big, composed of roundish and scalerenchymatous cells
Inter-vascular sclerenchyma	Not heavily lignified	Very heavily lignified

TABLE I—(*Contd.*)

	Sugarcane (P.O.J. 213)	Bamboo
Phlœm	Additional groups absent. Normal groups consisting of 2 big cells with 3 or 4 small cells at the top	Additional groups present. Normal groups consisting of cells of the same size, irregularly rosette-shaped
Metaxylem vessels	Not more than twelve (12)	12 to 15 or more
Endodermis ..	Only the inner tangential wall thickened	All walls thickened
Pericycle ..	Composed of irregularly arranged cells which are squarish in cross section	Composed of regularly arranged and radically elongated cells
Stem		
Epidermis ..	Cells similar, heavily lignified with a circular cavity inside	Cells dissimilar, not so heavily lignified, cavity angular
Cuticle ..	Thick and very prominent	Not very prominent
Cortex ..	Absent	Definite; about 5 rows of cells with chloroplasts
Bundle distribution	Not very closely packed. Plenty of parenchyma in between the bundles	Bundles very closely packed with narrow chains of parenchyma cells in between them
Bundle sheath ..	Not very highly lignified, continuous and not extending at the xylem pole forming a skirt	Very heavily lignified, more towards the xylem pole, forming a skirt; broken at the phlœm pole in the cortical bundles and broken at both poles in the medullary bundle
Phlœm ..	Broad groups with a concave top, consisting of small, angular sieve tubes with single parenchyma cells in between them	More or less triangular groups; sieve tubes round, big and with more than one parenchyma cell round them
Metaxylem vessels	Not very big in the medullary bundles	Big in the medullary bundles
Protoxylem ..	Extends beyond the limits of the meta-xylem vessels and gives the bundle an elongated shape	Confined to the limits of the lower boundary of the meta-xylem and gives the bundle a broad shape
Ground tissue ..	Cells big, angular and thin-walled	Cells small, round and lignified

TABLE I—(*Contd.*)

	Sugarcane (P.O.J. 213)	Bamboo
Starch ..	Absent	Present
Hollow in the stem	Absent	Present
Leaf		
Epidermis ..	Cuticle very thick and even	Cuticle not very thick but with cuticular knobs
Stomata ..	Not sunken in pits	Sunken in pits
Chlorenchyma ..	Rounded cells with even walls and without a definite palisade arrangement	Cells with walls in-folded and arranged in a palisade manner
Air cavities ..	Absent	Present on either side of the bundles
Mechanical tissues	Narrow ; cells not so heavily lignified	Forms a typical girder and cells heavily lignified
Hairs ..	Long silica hairs absent on the under-surface	Long silica hairs present on the under-surface
Sheath		
Epidermis ..	Cells not very heavily thickened	Cells very heavily thickened
Bundle ..	Placed towards the abaxial side	Placed towards the middle
Sclerenchyma ..	Present in the adaxial and abaxial sides of the bundle	Present only on the abaxial side but spreading
Lacunæ ..	Present as an irregular cavity	Absent ; or a definite and regular cavity if present
Inflorescence stalk		
Cortex ..	Absent	Present
Bundles ..	Closely packed without parenchyma in between	Bundles arranged with broad chains of parenchyma in between
Phloem ..	Cells angular and with single parenchyma cells	Cells round with more than one parenchyma cell in between
Ground tissue ..	Cells angular	Cells round

cane type. Among the first lot, two bamboo characters occurred more frequently. These are the verticillate arrangement of the spikelets (Pl. IX, Fig. 8) and straight rachises (Pl. IX, Fig. 7) instead of the zigzag ones found in the cane. The number of callus hairs showed an intermediate character in some, but there was no case where callus hairs were absent as in bamboo. The binate nature of branching, characteristic of bamboo, was found in a few hybrids. The nature and arrangement of the glumes in all cases resembled the mother. The fimbriate margin of the lodicules occurred in one case only. In a very few cases thin loduciles were also noticed, but they were not as membraneous as in bamboo. In the spikelets six stamens as in bamboo occurred in only two cases (Pl. IX, Fig. 11).

The three stigmas present in the bamboo spikelets have a special feature. The stigmas do not branch off from one point at the top of the ovary, but first two branches arise (Pl. IX, Fig. 10) and then one of these further branches into two. In a few hybrids (Pl. IX, Figs. 11–19) similarly branched stigmas were seen and they occurred in most of the spikelets of an inflorescence while a few spikelets had only two stigmas.

(*b*) *Anatomy*

The analysis for the anatomical characters includes the back crosses in addition to the F_1 and F_2 hybrids.

The root.—Table II shows the frequency of the bamboo characters inherited by the hybrids. The heavy lignification of the intervascular sclerenchyma (Pl. X, Figs. 5, 7, 9, 16, 17 and 18) was met with in 13 of the F_2 and 3 of the back crosses. The lignification was imtermediate in many cases but tabulations were made of those cases only where the lignification was as heavy as in bamboo. The extra phlœm groups occurred in 17 of the F_2s and 4 of the back crosses (Pl. X, Figs. 6, 8, 9 and 12). These extra phlœm groups were placed between the two phlœm groups without a protoxylem group in the middle (Pl. X, Fig. 16, 17, 18 and 20). Even though the position of these extra groups was not as in bamboo, they can be taken as inherited only from bamboo since in canes the extra phlœm groups are never found. So their occurrence was tabulated. Large number of metaxylem vessels as in bamboo (Pl. X, Fig. 4) were found in about 35 of the F_2s and 6 of the back crosses. This was the character which was inherited by the largest number of hybrids. Three of the F_2s and 3 of the back crosses showed the characteristic sclerenchymatous pith of bamboo with roundish cells. The big pith (Pl. X, Figs. 5, 8, 11 and 12) occurrred in eight of the F_2s and two of the back crosses. Only one of the 112 hybrids examined showed the pericycle as in bamboo (Pl. X, Fig. 20) composed of regularly arranged cells.

Stem.—In the stem, the cortex was definite as in bamboo (Pl. XI, Fig. 18), in 30 out of which 3 are of the back crosses (Pl. XI, Figs. 8, 9 and 10). The close packing of the peripheral vascular bundles (Pl. XI, Figs. 4 and 18) with chains of parenchyma cells

separating them was found only in 5 of the F_2s and one of the back crosses (Pl. XI, Fig. 16). Twelve hybrids showed their bundle sheath (Pl. XI, Figs. 19–27 and 29–31) broken, heavy, and spreading at the xylem region as in bamboo (Pl. XI, Fig. 23). Big sieve-tubes with more than one parenchyma cell surrounding them was seen in 7 of the F_2s and one of the back crosses (Pl. XI, Figs. 20, 22, 24, 29 and 30). Only four hybrids showed that the ground tissues (Pl. XI, Figs. 2, 7, 9 and 14) composed of roundish cells exactly as in bamboo (Pl. XI, Fig. 4) with starch grains. There were many with the ground tissue intermediate between that of the parents.

Leaves.—The structure of the leaf blade in the hybrids did not show definitely any bamboo characters though there were indications in one or two cases. In the case of the back crosses the bamboo characters were seen in the form of cuticular projections (Pl. XII, Figs. 8, 9 and 10) and long silica hairs, both these being very characteristic of the bamboo blade. Even where the characters of bamboo were inherited the frequency was very low. The cuticular knobs being found in only one F_2 hybrid and two of the back crosses, whereas the silica hairs only in two of the F_2 hybrids.

Leaf sheath.—The absence of lacunæ or presence of definite lacunæ as in bamboo occurred in seven hybrids (Pl. XII, Figs. 2–6). Thirteen hybrids showed the scalarenchyma only in the adaxial side of the sheath well developed (Pl. XII, Figs. 2–6). In seven hybrids the bundles were towards the middle as in the case of the bamboo.

Inflorescence rachis.—Bamboo characters were more pronounced and occurred more frequently in the inflorescence rachis than in the stem.

The bundles placed slightly apart as in bamboo was seen in 8 hybrids (Pl. XII, Fig. 14). The double sheath occurred in 3. Fifteen hybrid rachis showed the number of rows of bundles more than the number in cane (Pl. XII, Figs. 14–15). The phlœm cells in 6 of these (Pl. XII, Figs. 18, 19 and 20), were found with more than 1 parenchyma cell surrounding them. As in bamboo, the cells round the bundles were round in 8 of the hybrids (Pl. XII, Figs. 19 and 20). The ground tissue in bamboo inflorescence rachis is more lignified in cane and this character was seen in 10 of the hybrid inflorescence rachises.

In all these cases many intermediate characters were seen, but tabulations were not made of such cases.

The back crosses deserve to be dealt with separately. Twelve of them were studied and the observations were confined to the floral and anatomical characters only. Generally more bamboo characters were found in each of the back crosses as compared with the F_1s and F_2s. The frequency of occurrence of bamboo characters too was greater in the back crosses than in the F_1s or F_2s. The

additional groups of phlœm occurred in the root of 4 out of the 12 examined. Six out of 12 showed the number of metaxylem vessels as in bamboo. The bamboo pericycle with regular and radially elongated cells was seen in one of the back crosses only (Pl. X, Fig. 20). The roots of all the back crosses were interesting because every one of them showed at least one of bamboo characters such as the lignification of the interxylary sclerenchyma, the round celled pith, etc.

The stems of these back crosses too were very interesting. Characters like the broken spreading bundle sheaths were seen in 3/12. The bamboo ground tissue composed of roundish cells was inherited by about 2/12 of the back crosses, whereas only 2/100 of F_2 hybrids showed the same character.

Here too the leaves did not show many resemblances to bamboo. The stomata were sunken in two of the hybrid leaves as in Bamboo (Pl. XII, Fig. 11). In the seedling stage the leaves showed the prominent cuticular knobs of bamboo. The knobs were not found in the adult leaves.

In floral characters they were very interesting. They showed three stigmas and six stamens as in the F_2s. The inflorescence of only 5 numbers were examined and 3 of them showed 3 stigmas (Pl. IX, Fig. 11–19).

TABLE II

Showing the Frequency of Occurrence of Bamboo Characters in the Hybrids

Bamboo characters noted in the hybrids	No. of hybrids showing the character out of a total of 300 (F_1 and F_2) examined
1. Root eyes ascending	100
2. Leaf sheath bursting	98
3. Claw-shaped buds	60
4. Multiple buds	17
5. Surface hard, bamboo—coloured and shining ..	12
6. Leaf-scar with circlet of hairs	3
7. Root-eyes going above round the bud	2
8. Leaves spiral	1

TABLE II—(*Contd.*)

Total number examined for anatomy	F_1 and F_2 plants 100	Back crosses 12
Root		
1. Inter-vascular sclerenchyma heavy	13	3
2. Extra groups of phloem	17	4
3. Mataxylem vessels, 12–15 or more	35	6
4. Pith sclerenchymatous and composed of roundish cells	3	3
5. Big pith	8	2
6. Pericycle composed of regularly arranged cells elongated in cross section	..	1
Stem		
1. Cortex definite	27	3
2. Peripheral bundles closely packed, but separated by narrow ground tissue	5	1
3. Sheath broken, heavy and spreading at the xylem region	9	3
4. Sieve tubes big with more than one parenchyma cell surrounding them	7	1
5. Ground tissue composed of roundish cells with starch	2	2

Total number examined for anatomy	F_2 and F plants 100	Back crosses 12
Leaf blade		
1. Mechanical tissue a typical girder	2	..
2. Lower epidermis with cuticular knobs and short spinous hairs	1	2
3. Long silica hairs	2	2
4. Stomata in pits	..	2
Leaf sheath		
1. Lacunæ absent or if present definite	4	3
2. Sclerenchyma well developed only in the adaxial side	9	4
3. Bundle placed towards the middle	5	2

TABLE II—(*Contd.*)

Total number of plants examined for inflorescence	F_2 75	Back crosses 5
1. Spikelets verticillate	20	..
2. Rachis straight	26	..
3. Callous hairs sparse	2	..
4. Lodicules three	1	..
5. Lodicules fimbriate at the edges and thin ..	2	..
6. Stamens six	2	1
7. Stigmas three	6	3

Total number in which anatomy of inflorescence rachis was studied	F_2 40	Back crosses 5
1. Bundles placed slightly apart	8	..
2. Double sheath	3	..
3. Number of rows of bundles more than in P.O.J.	15	..
4. Phlœm cells round with more than one parenchyma cell surrounding each	6	..
5. Cells round the bundles roundish	8	..
6. Ground tissue more lignified than in P.O.J. ..	10	..

V. DISCUSSION

The results of the above study very clearly emphasise the fact that the hybrids are genuine. Certain of the characters exhibited by the hybrids could have been derived only from the bamboo. Such characters are (1) in the root, the occurrence of the additional phlœm groups, the pericycle consisting of a regular layer of radially elongated cells, the big pith consisting of thick-walled, lignified and rounded cells, (2) in the stem, the definite cortex, the close segregation of bundles with narrow chains of parenchyma cells in between them, the heavy sheath extending towards the xylem pole, the characteristic break in the bundle sheath, the rounded phlœm elements surrounded by parenchyma cells, and the ground tissue, composed of small rounded cells; and (3) in the leaves, sunken stomata.

In the field where the bamboo hybrids were grown along with other sugarcanes, it was difficult to distinguish them from the others, since in appearance and growth form the hybrids were similar to canes. But on closer examination, it was possible to make out the influence of the male parent. Such of the male characters as were found in the hybrids have been described.

The analysis as given in Table III for the external characters of a few hybrids selected out of the total number examined reveals certain points of interest as regards the nature of the inheritance from the male parent.

(*a*) *External Morphology*

The group of characters constituting any one morphological unit, for example, the bud in bamboo, gets split up into different units as they are inherited by the hybrids. The buds in the bamboo are big, claw shaped, double or multiple and bursting through the sheath. But in the hybrids the group of characters gets split up into different single characters. They may occur singly or in combination of more than one. In no case are all these characters seen together. In some, the claw shape of the bud alone was seen. In others, the buds were seen bursting through the sheath, but neither big nor claw shaped. In still others, the big-size of the bud alone occurred. Each hybrid inherited a few characters from the father and a larger number from the mother. So also is the case of the root eyes. In bamboo, they bulge beyond the surface and the rows of root eyes go round above the bud. Some of the hybrids had bulging root eyes. In some the rows of root eyes ascend on either side of the bud, but not completely going round it and in two cases the root eyes were seen going round above the bud as in bamboo. The ascending rows of root eyes can be considered an interemediate character because in bamboo they are seen going above the bud and in cane not even ascending. The hard, hollow stems of bamboo occur in the hybrids as hard stems only or hollow stems only and never both together. In the case of the leaves, both external and internal characters were very poorly inherited. Only the spiral arrangement of the leaves occurred in two of the hybrids. Small petioled leaves as in the bamboo were not at all seen in any of the hybrids. On the whole we see that some of the characters were inherited by a large number of the hybrids whereas the others were inherited by only a few. For instance, the circlet of hairs in the leaf-scar was found only in two cases. Still some other characters of the bamboo were completely absent in the hybrids.

The morphology of the inflorescence too shows the same sort of splitting of the parental group of characters into unit characters when they are inherited by the hybrids. In bamboo, the inflorescence rachis is angular, shiny, with the sessile big spikelets verticillate on binate secondary peduncles and with sparse callus hairs. The spikelets show three big lodicules with fimbriate margins, six stamens, an ellipsoid ovary with two styles and three stigmas. In

TABLE III

Showing the Occurrence of Bamboo Characters in Certain of the F_2 Hybrids and Back Crosses

Sugarcane × B. hybrids F_2 of No. 9	Multiple bud	Double bud	Big buds	Buds claw-shaped	Leaf scar with circlet of hairs	Leaf sheath burst-ing	Hairs on the under surface of leaf	Hard bamboo coloured and shiny	Root eyes ascend-ing	Root eyes bulg-ing	Root eyes going above the bud
Seedling number											
26				X		X					X
36				X		X			X		
38						X					
43				X		X					
45						X				X	
48				X		X		X	X	X	
49				X		X		X		X	
52					X	X					
56			X	X		X			X	X	
57									X		
66			X	X		X					
74			X	X		X					
92						X			X		
93									X	X	
95				X				X	X	X	
140	X			X	X	X				X	
195		X		X		X			X		X
201				X		X			X		
209				X		X	X				

Note.—The mark X = character present

TABLE III—(*Contd.*)

Inflorescence Rachis

Sugarcane × B. hybrids F_2s of No. IX and back crosses with bamboo	Rachis	Angular and pistillate	Spikelet verticillate	Binate	Peduncle straight	Callous hairs sparse	Spikelets sessile	Spikelets big	Lodicules	Big and not fleshy	Lodicules fimbriate at the edge	Stamens 6	Stigmas 3	Ovary elipsoidal
Seedling number														
30	X					X				X	X	X	X	
91			X	X	X	X	X	X			X	X		
115					X			X						
182			X		X		X	X						
114					X			X					X	
197			X	X										
9 × B_3									X				X	X
9 × B_5													X	
9 × B_3			X										X	

Note.—The mark X = character present

the hybrids these characters are seen in no case all together. The rachis in some is shiny. In No. 91 (F_2) a combination of more than one of these characters is seen. In others, three stigmas and six stamens go together with the lodicules alone as in the cane.

As regards ovary, styles and stigmas, varied combinations are met with such as round ovaries with three styles, and three stigmas, round ovaries with two styles and three stimgas (Pl. IX, Figs. 12, 13, 15 and 17), ellipsoidal ovaries with two styles and two stigmas (Pl. IX, Fig. 16) and ovaries of intermediate shape with two styles and three stigmas (Pl. IX, Fig. 13). In some, except for the three stigmas all other parts were exactly as in the cane.

(*b*) *Anatomy*

The hybrids which showed resemblances to bamboo in their external morphology did not necessarily show any resemblances to bamboo in their anatomy. As for example, No. 140 showed nine morphological characters resembling bamboo, but there was no resemblance in its internal anatomy to bamboo. This statement can be reversed while referring to cases such as No. 82 and No. V × Bamboo (No. 4) where the plants were purely after the mother in external features, but the internal anatomy showed the greatest similarity to bamboo especially of the stem. But on the whole, the internal anatomy of the hybrids show a more interesting sort of blending and splitting of the parental characters.

In bamboo, the root consists of a big stele and a comparatively narrow cortex whereas the cortex in cane is big and the stele small. The pith of the bamboo root is big and consists of small rounded cells with lignified walls. The hybrids in a few cases as in No. IX × Bamboo (No. 2) show a big stele almost of the same size as that of bamboo. But in F_1 XVII and No. IX × bamboo (Nos. 3 and 7) (F_2) the stele had a size intermediate between the parents. Some very thin roots showed lignified pith as in bamboo, but there were also cases of small roots with round but thin walled pith cells, big pith with sclerenchymalous cells and big pith with thin walled rounded cells. In No. IX × bamboo (No. 2) (Pl. X, Fig. 12) the pith was big consisting of sclerenchymatous but slightly angular cells. So when the bamboo characters are inherited by the hybrids, each gets only one or two of the father's characters.

The bamboo type of heavily lignified interxylary sclerenchyma was met by with in many hybrid roots. But in such roots there were cases where the metaxylem vessels were farther apart, with many protoxylem and phlœm groups between them as in bamboo. In other cases, though the interxylary sclerenchyma was heavily lignified the number and arrangement of the metaxylem, protoxylem and phlœm groups were as in cane. The occurrence of big pith was always correlated with an increased number of metaxylem vessels as in bamboo. In certain cases an increased number of metaxylem arranged as in bamboo but with the pith small as in cane was seen. In others, though the number was small the distribution of the metaxylem vessels was as in bamboo.

The phlœm in the bamboo root is very interesting. The normal phlœm groups have an irregular rosette shape with small sieve tubes (Pl. X, Fig. 15) whereas in the canes there are one or two big phlœm vessels with three parenchyma cells on top (Pl. X, Fig. 13). Additional phlœm groups occur in the bamboo root between the above the metaxylem vessels (Pl. X, Fig. 14). Such additional phlœm groups are characterised by a central big sieve tube almost surrounded by parenchyma cells. The inheritance of both the rosette and the additional groups of phlœm of the father by the hybrids formed an interesting study. Some hybrids showed the rosette phlœm group as in bamboo, but irregular because of the difference in size of the constituting phlœm vessels. In some, the additional groups of phlœm occurred either between two rosette groups or between two groups of the cane type, but not in places where they normally occur in bamboo. In some others, such additional groups were a mere repetition of the normal phlœm group of the father or mother. In No. 1 hybrid with its heavy interxylary sclerenchyma (Pl. X, Fig. 16), all the phlœm groups were exclusively of the bamboo additional type.

The pericycle of two hybrids out of which one is a back cross of No. IX × bamboo (No. 3) (Pl. X, Fig. 20) showed the characteristic bamboo pericycle which consists of regularly arranged thick walled radially elongated cells. The bamboo type of endodermis never appeared in any of the hybrids not even in such cases where the pericycle was distinctly of the bamboo type. The root in the hybrids on the whole shows a very interesting blending of the parental characters. Each root shows either one character of bamboo alone or more than one in combination.

The stem characters showed still greater complications. The epidermis of bamboo does not form a layer of cells of uniform appearance but consists of cells of different shapes and sizes with their walls thickened all round. In cane the outer tangential wall of the epidermal cells is heavily thickened. Similarly the hypodermal cells have their inner tangential walls heavily lignified and striated. Bamboo also shows a definite cortex. Apart from these characters the peripheral bundles of the bamboo stem are all closely packed with chains of parenchyma cells separating them.

In the hybrids all these characters are inherited singly or in groups of two or more. Some showed the bamboo epidermis with a cane hypodermis while in others were seen the cane epidermis with bamboo hypodermis. So also was the case with the cortex and the bundle arrangement. There were cases where a definite cortex was seen without the crowding of the bundles. In some others the crowding of the bundles without a definite cortex was seen. The peripheral bundles of bamboo have a peculiar shape with their bundle sheaths broken at the phlœm pole and forming a sort of cap over the phlœm region and at the xylem pole the sheath extends and forms a skirt consisting of an inner region with very thick walled cells and an outer region with cell walls less thickened.

Certain hybrids as No. 82 (F_2) No. V × bamboo No. 4 (Pl. XI, Fig. 16) showed the crowding of the bundles as well as the shape and behaviour of the sheaths. The bundles were separated by narrow chains of parenchyma cells. The sheath in such cases were big forming the characteristic sheath as in bamboo. But they did not show the break of the bamboo sheath at the phlœm pole. On the whole, these two hybrids came nearest bamboo and were as hard as bamboo for sectioning. There were hybrids which showed the heavily lignified sheath, but without the characteristic extension to form the skirt and others which showed the extension of the sheath without the heavy lignification. In some others where the sheaths were very heavily lignified the bundles were arranged apart as in bamboo. Lignification of these sheath cells in hybrid like No. 82 (F_2) was exactly as in bamboo, but the individual cells were much bigger (Pl. XI, Fig. 20). In some other cases the cell size was as in bamboo, but the lignification less than in bamboo but decidely more than in cane. The rounded cavities of the bamboo sclerenchyma cells were well seen in a few hybrids.

In the inheritance of the characters of the bundles similar features were noted. The bamboo bundles were characterised by big, round, phlœm elements each surrounded by a number of parenchyma cells. The whole phlœm group itself has a shape different from that of cane being convex at the top instead of concave as in cane (Pl. X, Figs. 19–23, 28 and 32). In some hybrids the phlœm group has the shape of that of the bamboo phlœm groups but with the elements angular and small as in cane (Pl. X, Figs. 24 and 30). In some others, the elements were round and big without the paranchyma cells surrounding them. In rare cases, there were combinations of round phlœm elements with more than one parenchyma cell round them. There were only one or two hybrids where the shape of the phlœm groups and the round shape of its elements occurred together as in bamboo. But there were several cases where both the phlœm elements and the shape of phlœm showed an intermediate character.

The xylem vessels of the hybrid bundles too showed characters of bamboo. Big xylem vessels occurred but they were not placed far apart as in the bamboo but placed close together as in cane. In some, the metaxylem vessels were small but placed far apart as in bamboo. In a few, the size of the metaxylem vessels was intermediate. The position of the protoxylem in bamboo is in between the two metaxylem vessels and within the limits of their dimensions (Pl. X, Fig. 32). Some of the hybrids had the protoxylem inside the limits of the metaxylem as in bamboo and not as in cane (Pl. X, Fig. 28) where it projects outside the limits of the metaxylem vessels (Pl. X, Figs. 31). This character of the bamboo in cases where it is inherited gave the bundles the exact shape of the bamboo bundles. In some hybrids, according to the position of the protoxylem vessels there was a mixture of bamboo shaped bundles and cane shaped bundles in the same cross section, but the former were only a few. In No. V ×

bamboo No. 4 (Pl. X, Figs. 5 and 14) there were some bundles with the broken sheath as in bamboo and some bundles without the broken sheath as in cane. Many intermediate characters were seen in the case of the bundles in their whole shape, size, shape of the elements and their distribution.

The ground tissue in bamboo consists of round, small cells with thickened walls, whereas, in cane, the ground tissue is composed of big angular thin walled cells. The hybrids in certain cases, showed round, small, thin walled cells and in some others thick walled round, big cells and in certain others thick walled, angular, big cells. Most of them showed the cane type of ground tissue consisting of big, angular, thin walled cells. Intermediate stages in size, shape and thickening of the cells of the ground tissue were seen in a few hybrids.

The leaves of the hybrids gave the least number of points of resemblance to the male parent. The palisade nature of the chlorenchyma and the air spaces on either side of the bundles were completely absent in the leaves of the hybrids. Few of the seedlings of the back crosses showed the characteristic cuticular knobs seen in bamboo but these knobs were absent in the leaves of the adult plants (Pl. XII, Figs. 9 and 10). The stoma of bamboo is sunken, whereas in the cane there is no definite pit. In two of the back crosses (Pl. XII, Fig. 11) the sunken stoma was noted. The sclerenchyma above the bundle in some of the hybrids showed the girder shape as in bamboo.

The structure of the hybrid leaf sheath also shows a few characters of the father and a few intermediate between the two parents. The thick walled epidermis of the bamboo leaf sheath was met with in some of the F_1s and F_2s of No. IX. Lacunæ were absent in some and when present in a few others, were seen as definite cavities as in bamboo. The absence of the sclerenchyma band on the adaxial side of the vascular bundle is a character inherited from the father, because in cane this is a definite character.

The inflorescence stalk showed the same results as in the stem, but here they were much more definite. A section of the inflorescence stalk of the cane shows a very close packing of the bundles near the epidermis without the chains of parenchyma in between them; but in bamboo a definite cortex with the bundles arranged with parenchyma chains in between them is noted. The definite cortex of the father was completely absent in all the 40 stalks examined. But the distribution of the bundles showed certain resemblances to that of bamboo. In B.H.V. (6) (Pl. XII, Fig. 15) the bundles were arranged as in bamboo, but the distance between the bundles was more than in bamboo. The phlœm in many showed the rounded sieve tubes. The shape of the whole phlœm in a few cases was also similar to bamboo (Pl. XII, Fig. 20).

There are certain bamboo characters that were not inherited by the hybrids. They are :—

(1) Leaf as narrow and thin as in bamboo.
(2) Leaf small with a petiole.
(3) Endodermis—all walls thickened.
(4) The complete breaking of the medullary bundle sheaths at the xylem as well as the phlœm poles.
(5) Palisade chlorenchyma.
(6) Air cavities on either side of the leaf bundles.
(7) Horny glumes in the spikelets.
(8) Three lodicules, thin and fimbriate.

VI. Conclusion

The study of the internal anatomy was much more interesting than that of the external morphology and the former revealed the peculiar and complicated nature of inheritance of parental characters to a much greater extent than the latter.

The roots and stems, as a whole, seem to have inherited the maximum number of characters from the father whereas the leaves and leaf sheaths inherited the least number. The inflorescence axis was found to be the best for such comparative study, for they gave very definite results. On the whole the study has shown that there is little doubt as regards the genuineness of the cross between the sugarcane and the bamboo. It is also seen that the inheritance of morphological and anatomical characters is of a very complex nature. The multiplicity of characters comprising any one morphological or anatomical unit was found to split up during inheritance by the hybrids. It has opened up the possibility of isolation and recognition of such characters.

Acknowledgement

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Summary

1. The study of the sugar cane × bamboo hybrids was undertaken with the object of finding out (1) whether the cross between cane and bamboo was genuine, (2) the nature of the inheritance of bamboo characters in the hybrids.

2. About 312 hybrids, including three generations namely, F_1, F_2, and the back crosses, were studied. External morphology of the vegetative and reproductive parts, and the anatomy of the vegetative parts were examined.

3. The characters of the hybrids showed a combination of the characters of the female and male parents.

4. The characters of the mother occurred more abundantly than those of the father.

5. The back crosses showed the maximum number of bamboo characters in all respects.

6. The roots inherited more bamboo characters than the stems, and the stem and inflorescence rachis showed more characters than the leaf sheath or leaf blade.

7. The inflorescence rachis was found to be the best for such a study since the characters of the parents appeared clear cut in them.

8. Attention is drawn to the fact that separate characters comprising one morphological unit such as a bud or a vascular bundle get isolated and one or more are inherited by the hybrids, but never all the characters together.

BIBLIOGRAPHY

1. Beck, P. V. (1927) .. " Comparative anatomy of certain hybrid shrubs and their parents," *Kansas Univ. Bull.*, No. 17, 367–95.

2. Brandza, M. (1890) .. ' Recherches anatomiques sur les hybrides," *Rev. Gen. Bot.*, **2**, 301–05, 432–45, 471–79.

3. Brown, H. B. (1913) .. " Form and structure of certain plant hybrids in comparison with the form and structure of their parents," *Mississippi Agr. Expr. Station Tech. Bull.*, No. 3.

4. Charlesworth, J., and Ramsbottom, J. (1916–17) " On the structure of the leaves of hybrid orchids," *Proc. Linn. Soc., Lond.*, 9–10.

5. Funaoka, S. (1925) .. " Der anatomische Bau des Blattes des Bastardes *Mirabilis jalapa* × *Mirabilis longiflora*, verglichen mit den Ellenpflanzen," *Zeitschr. Indukt. Abst. vererb.*, **39**, 288–92.

6. Macfarlane, J. M. (1892) " A comparison of the minute structure of plant hybrids with that of the parents, and its bearing on biological problems," *Trans. Roy. Soc., Edinburgh*, **37**, 203–86.

7. Papadopoulos Sophia (1928) " A Morphological comparison of leaflets of a hybrid cycad and the two parents," *Bot. Gaz.*, **85**, 30–45.

8. Russell, Alice, M. (1919) " The macroscopic and microscopic structure of some hybrid Sarracenias compared with that of their parents," *Contrib. Univ. Pennsylvania, Bot. Lab.*, **5**, 3–41.

9. Sinnot, Hougtalig and Blackslee (1934) " The comparative anatomy of the extra chromosomal types in *Datura stramonium*," *Carn. Inst. Wash. Publ.*, 451, 1–50.

10. Williams, C. F. (1923) " Hybridisation of *Ratis rotundifolia*. Inheritance of anatomical characters," *North Carolina Agr. Exper. Stan. Tech. Bull.*, No. 23, 1–32.

EXPLANATION OF PLATES AND FIGURES

PLATE IX

FIG. 1. Single buds in cane (P.O.J. 213) multiple buds in bamboo and multiple buds in hybrids.
FIG. 2. Single buds in cane and multiple buds in bamboo and the hybrids.
FIG. 3. Buds adpressed to the stem in cane and claw-shaped buds in bamboo and hybrids.
FIG. 4. Leaf scar without hairs in cane and with hairs in bamboo and hybrids.
FIG. 5. Root eyes not ascending in cane, and going over the bud in bamboo and hybrids.
FIG. 6. Leaves alternate in cane and spiral in bamboo and hybrid.
FIG. 7. Zigzag rachises in cane and straight rachises in bamboo and hybrid.
FIG. 8. Two spikelets at each node in cane and verticillate spikelet in bamboo and hybrid.
FIG. 9. Sugarcane pistil.
FIG. 10. Bamboo pistil.
FIGS. 11–19. Pistils and stamens of hybrids (F_2s of No. IX and back crosses).

PLATE X

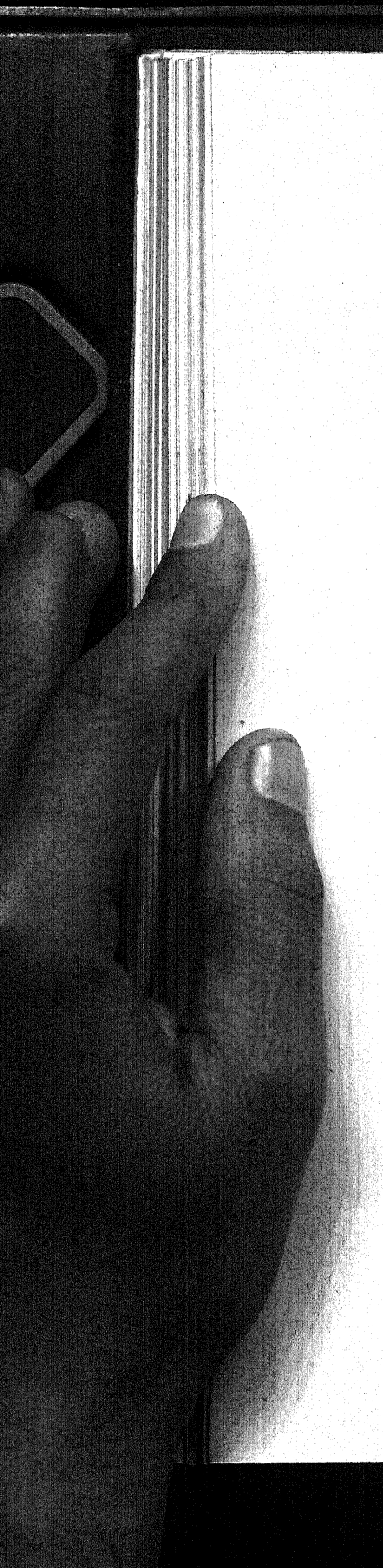
FIGS. 1 & 13. Sugarcane (P.O.J. 213) root.
FIGS. 4, 14 & 15. Bamboo root.
FIGS. 2 & 3. Roots of F_1 Hybrids.
FIGS. 5–8 & 16. Roots of F_2 Hybrids.
FIGS. 9–12 & 17–20. Roots of (Sugarcane × Bamboo) × Bamboo.

PLATE XI

FIGS. 1 & 15. Sugarcane (P.O.J. 213).
FIGS. 4 & 18. Bamboo.
FIGS. 2 & 3. F_2 Hybrids.
FIGS. 5–10 & 16 & 17. F_2 Hybrids.
FIGS. 11–14. (Sugarcane × Bamboo) × Bamboo.
FIG. 19. Sugarcane (P.O. J. 213) peripheral bundle.
FIG. 23. Bamboo peripheral bundle.
FIGS. 20–22. Peripheral bundles of F_2 Hybrids from No. IX.
FIGS. 24–27. Peripheral bundles of the back crosses (Sugarcane × Bamboo) × Bamboo.
FIG. 28. Sugarcane (P.O.J. 213) Medullary bundle.
FIG 32. Bamboo Medullary bundle.
FIGS. 29–31. Medullary bundles of hybrids.

PLATE XII

FIG. 1. Sugarcane (P.O.J. 213).
FIG. 2. Bamboo.
FIG. 3. F_1 Hybrids.
FIGS. 4 & 5. Back crosses.
FIG. 6. F_2 No. IX Hybrid.
FIG. 7. Sugarcane leaf cuticle.
FIG. 8. Bamboo leaf cuticle.
FIGS. 9 & 10. Leaf cuticle in the back crosses.
FIG. 11. Stomata in the leaves of the parents and the hybrids.
FIG. 12. Sugarcane (P.O.J. 213) inflorescence stalk.
FIG. 16. Bamboo.
FIGS. 13–15. F_2 Hybrids.
FIG. 17. Medullary bundle of sugarcane.
FIG. 21. Medullary bundle of bamboo.
FIGS. 18–20. Medullary bundles of the F_2 Hybrids.



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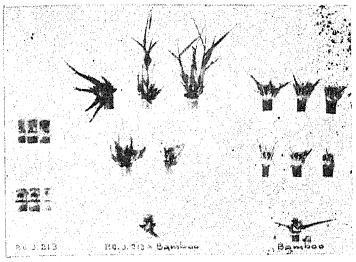

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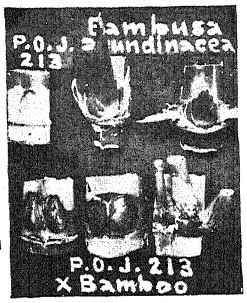

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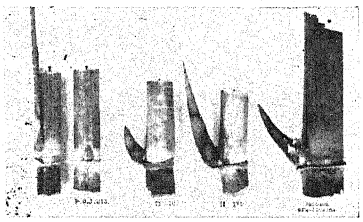

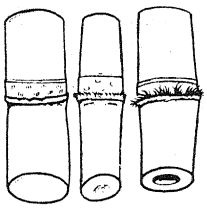

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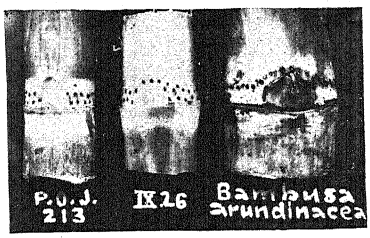

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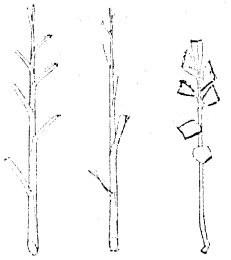

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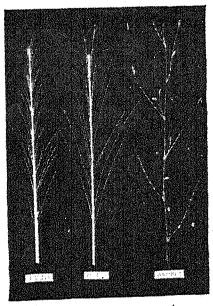
Inflorescence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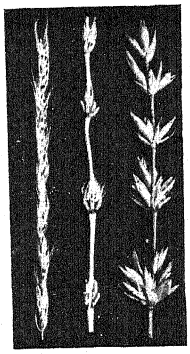
Spikelet arrangement
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Sugarcane (POJ 213)
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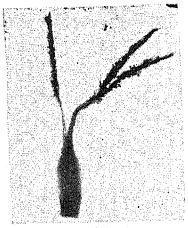
Bamboo
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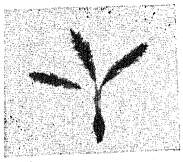
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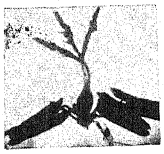
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F2s

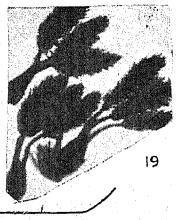
(Sugarcane × Bamboo) × Bamboo ♂


15


16


17


18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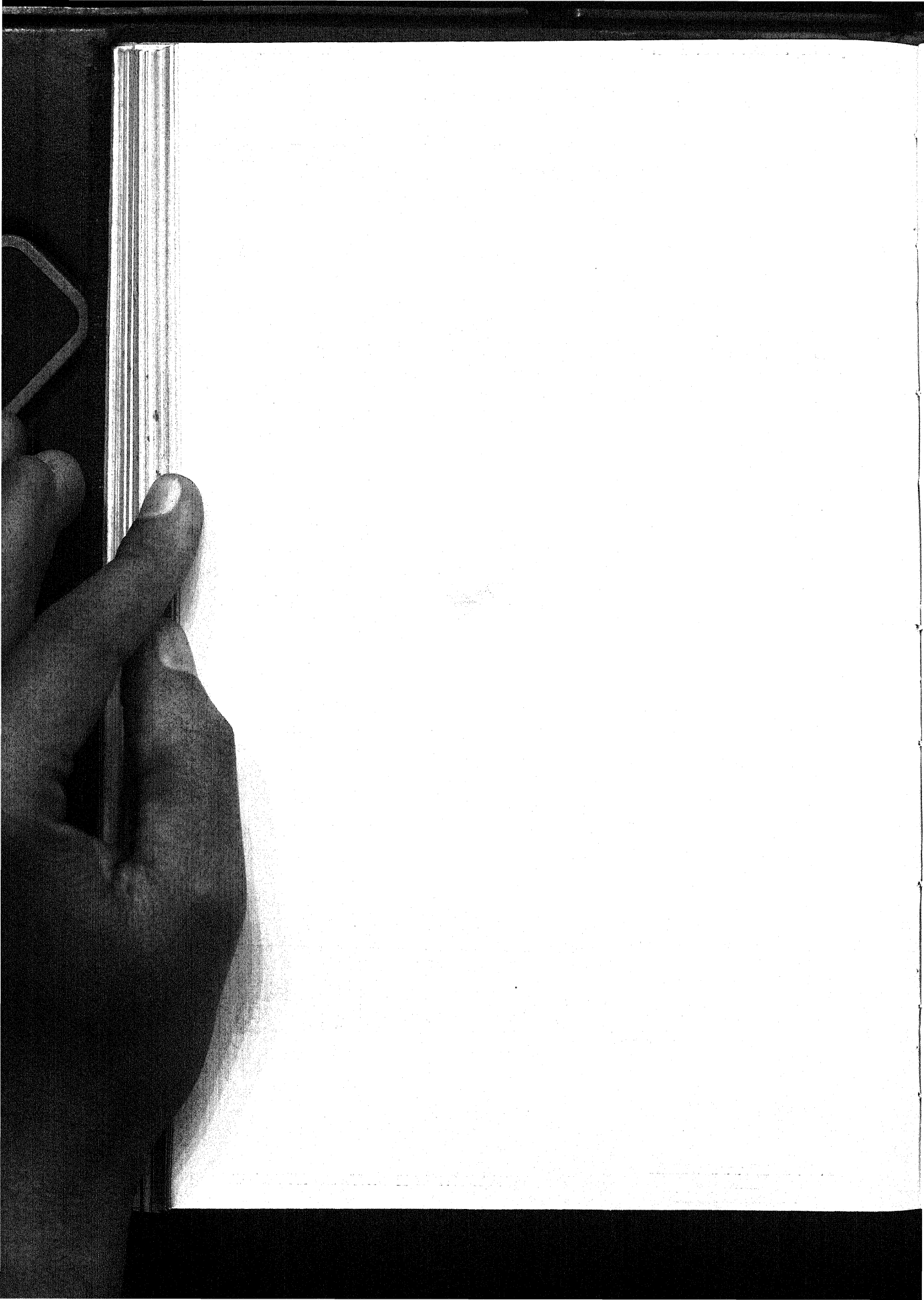
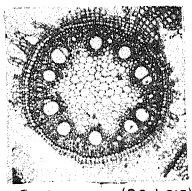
(Sugarcane × Bamboo) × Bamboo ♂

P. R. B. KUTTY AMMA
AND
T. EKAMBARAM

SUGARCANE X BAMBOO HYBRIDS



Root Anatomy.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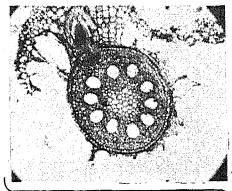
Sugarcane (P.O J 213)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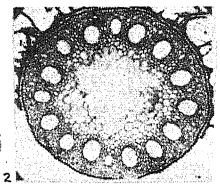
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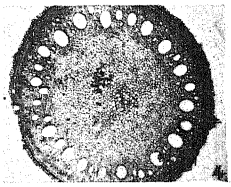
F 1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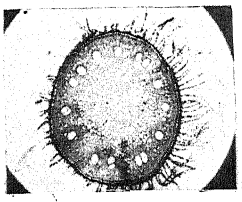
Bamboo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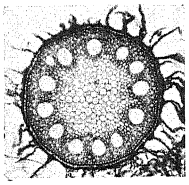
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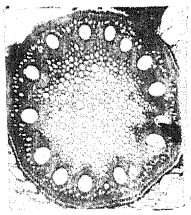
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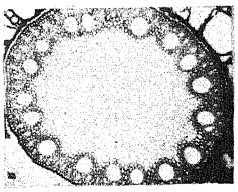
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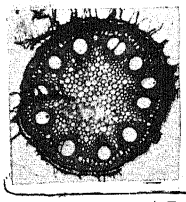
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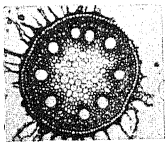
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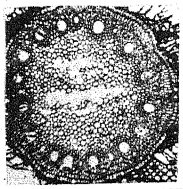
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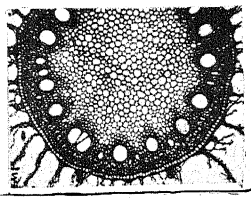
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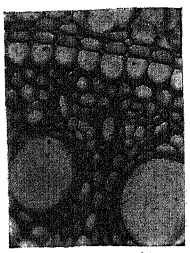
(Sugarcane x Bamboo) x Bamboo ♂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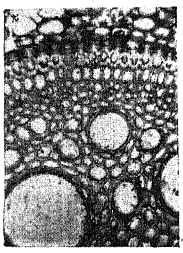
Sugarcane (P.O J 213)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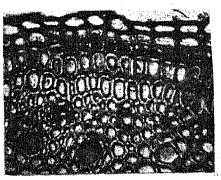
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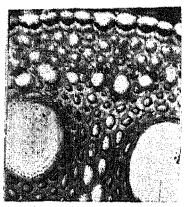
Bamboo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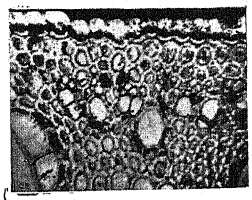
F 2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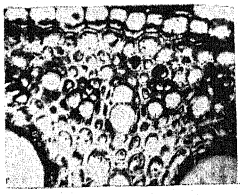
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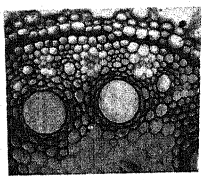
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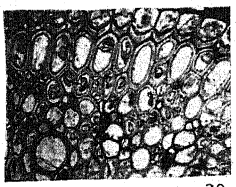
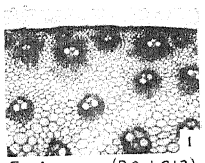

20

(Sugarcane x Bamboo) x Bamboo ♂

P. R. B. KUTTY AMMA
AND
T. EKAMBARAM

SUGARCANE X BAMBOO HYBRIDS

Stem Anatomy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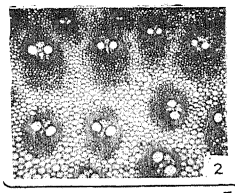
Sugarcane (P.O.J. 213)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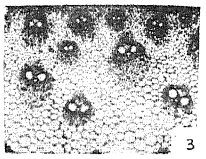
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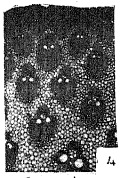
F. 1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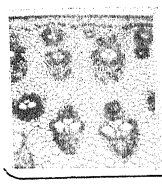
Bamboo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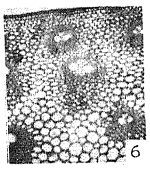
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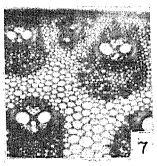
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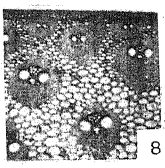
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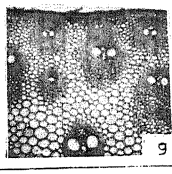
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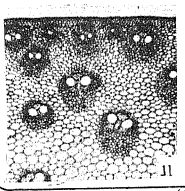
F 2s of Nº IX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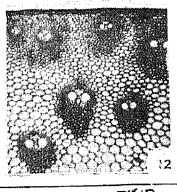
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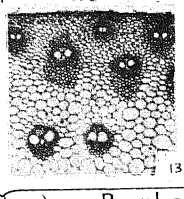
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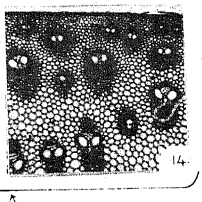
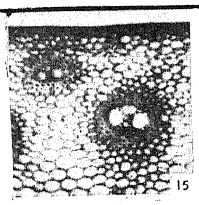

14

(Sugarcane x Bamboo) x Bamboo ♂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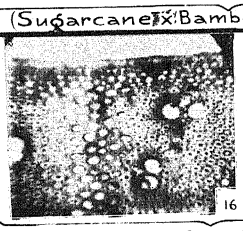
Sugarcane (P.O.J. 213)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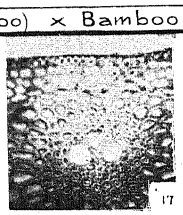
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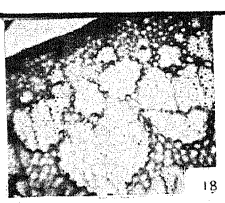
F 2s of Nº IX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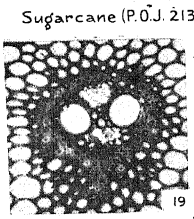
Bamboo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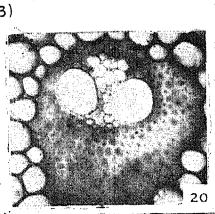
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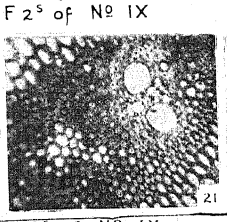
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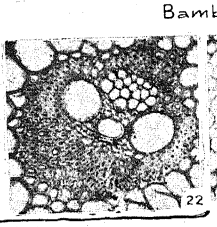
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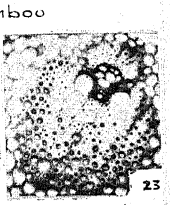
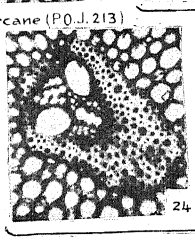

23

Sugarcane (P.O.J. 213)

F 2s of Nº IX

Bamboo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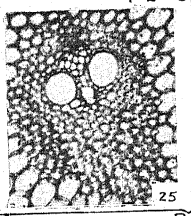
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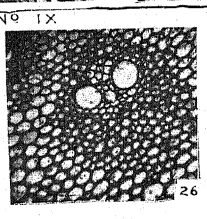
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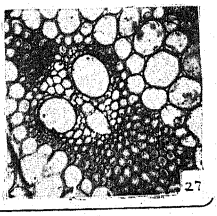
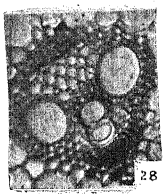
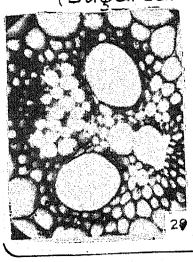

27

(Sugarcane x Bamboo) x Bamboo ♂


28

Sugarcane (P.O.J. 213)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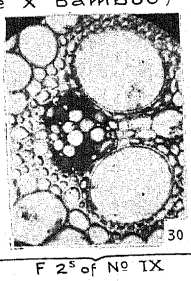
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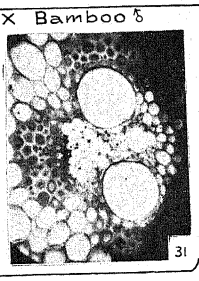
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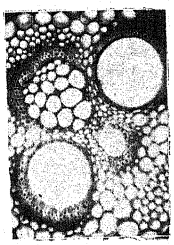
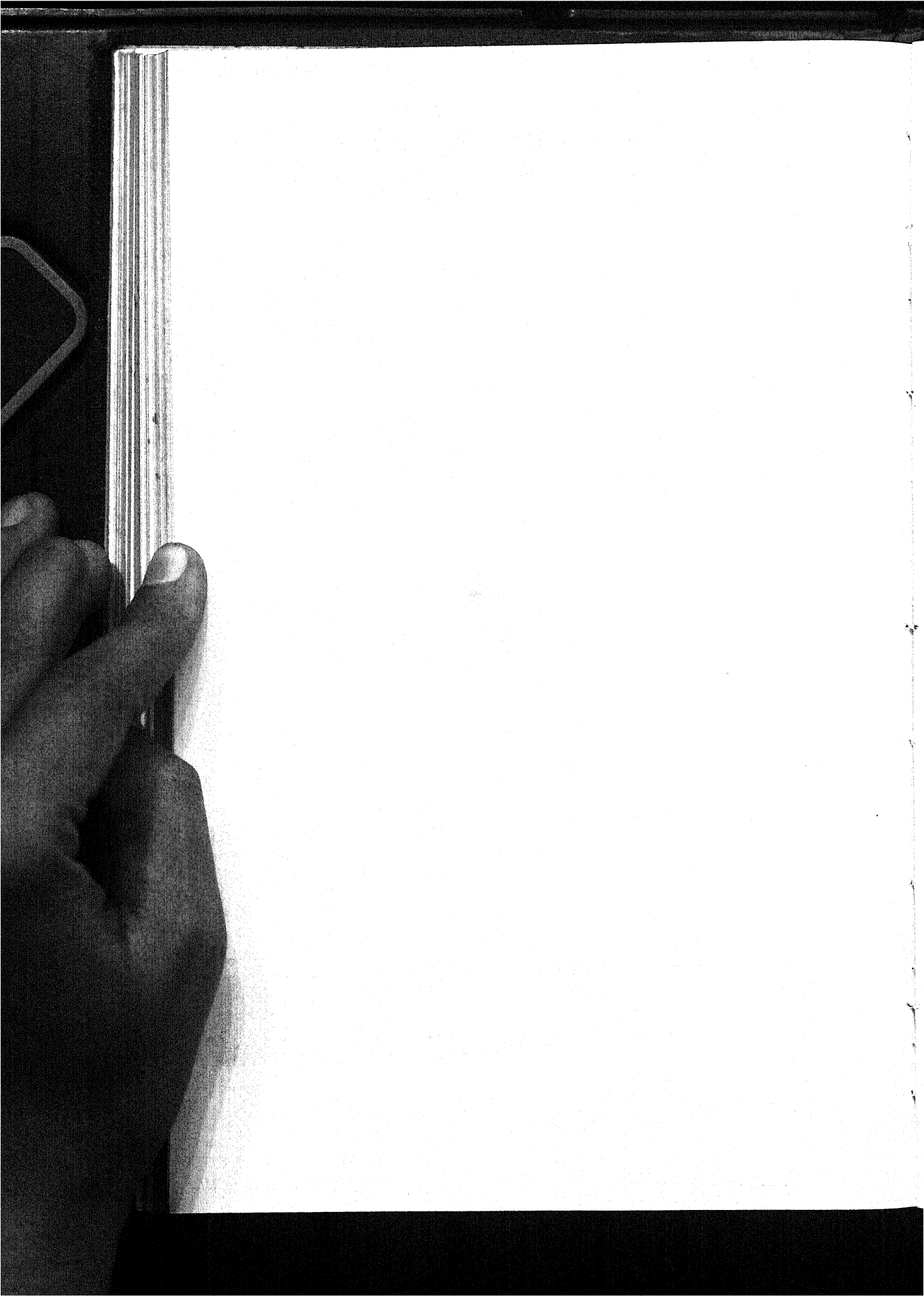
F 2s of Nº IX

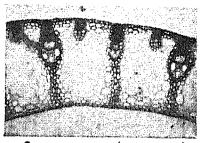


Bamboo

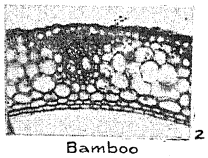


Anatomy of leaf & inflorescence rachis

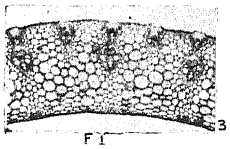
Leaf Sheath



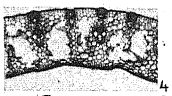
1 Sugarcane (P.O.J. 213)



2 Bamboo



3 F 1



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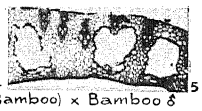
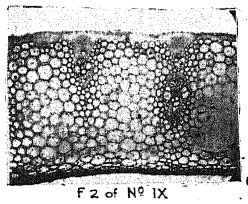
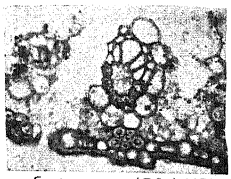


5 (Sugarcane × Bamboo) × Bamboo ♂

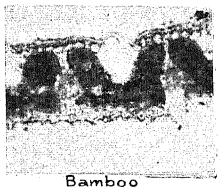


6 F 2 of No IX

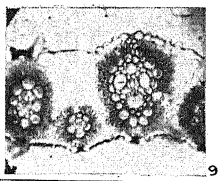
Lamina



7 Sugarcane (P.O.J. 213)



8 Bamboo



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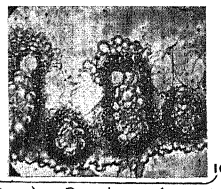
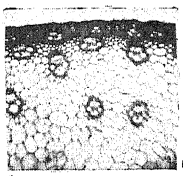


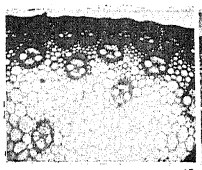
10 (Sugarcane × Bamboo) × Bamboo ♂

11

Inflorescence Stalk



12 Sugarcane (P.O.J. 213)



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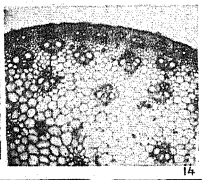

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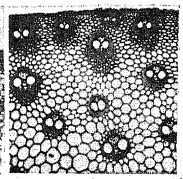

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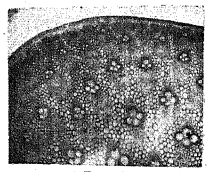

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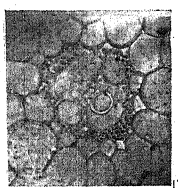

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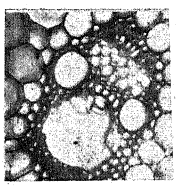

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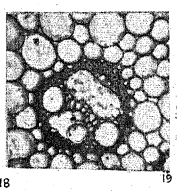

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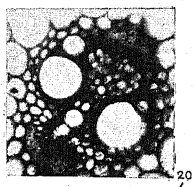

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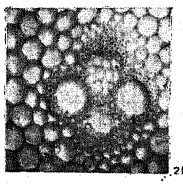

21 Bamboo

P. R. B. KUTTY AMMA
AND
T. EKAMBARAM

SUGARCANE X BAMBOO HYBRIDS

THE CHAROPHYTES OF THE BOMBAY PRESIDENCY—II

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Received for publication on August 31, 1939

THE author has previously recorded sixteen species of Charophytes from the Bombay Presidency in this *Journal* (1931, 1935). The present paper is primarily meant to communicate four additional species since found. The opportunity is also taken to publish new localities and descriptions of the species just listed in the past two papers.

In addition to the twenty species collected by the author there are four species known from the Presidency, *viz.*, (1) *Nitella dispersa* Br. (2) *Nitella batrachosperma* Br., a doubtful specimen obtained by Prof. Agharkar in 1912 from Kathiawar. (3) *Nitella microglochin* Br. collected by Woodrow at Ratnagiri in 1893 and (4) *Nitella myriotricha* Kütz. prox. collected by Burkill at Amboli in 1902. They are so far not met with.

I. NITELLA

1. *Nitella opaca* Ag.—A. Braun and O. Nordstedt, *Fragmente einer Monographie der Characeen*, 1882, p. 32 ; Groves, *Journ. Bot.*, 1880, XVIII, p. 166, t. 210, f. 19.

Dicœcious. Stem 500–750 μ thick ; internodes 2–4 times the length of the branchlets. Branchlets dimorphic, sterile whorls of 6–7 simple or once forked stoutish branchlets ; secondary rays 2–3, 1-celled, with mucronate tips. Fertile whorls of usually 6–7 short branchlets, once forked, with mucronate tips, forming dense or lax heads. Oogonia solitary or geminate, 600–700 μ long, 450–500 μ broad ; convolutions 7–9 ; spiral cells sometimes swollen at the apex. Oospore rounded, 400 μ long, 375 μ broad, outer membrane brownish, irregularly granulated. Antheridium large 700–860 μ in diameter.

Locality.—Warasia Tank, Baroda, April 1938.

This species in almost all essentials agrees with *N. opaca* Ag. but differs somewhat in the markings of the membrane of the oospore which is not scabrous in the oospores examined. But the character of the membrane is variable both in *N. opaca* Ag. and *N. flexilis* Ag. The antheridium tends to be larger than in typical *N. opaca* Ag. The branchlets, especially the dactyls, are unusually long and the apices of the dactyls are rather more acute than in the type. In spite of these differences the plant is in all probabilities *N. opaca* Ag. It was in this species that Groves had found an oogonium which had six spiral cells in place of the usual five.

This is the first record of this species from India which considerably extends its known distribution. It mainly occurs in Europe, N. Africa and America.

2. *Nitella mucronata* Miquel. Braun and Nordstedt, *op. cit.*, p. 50; A. Braun, *Charac.* Africa, 1867, p. 810; Groves, *op. cit.*, 1880, p. 165, t. 210, f. 16.

Monœcious. Stem moderately stout, 450–500 μ; internodes longer than the branchlets. Branchlets 5–6 in a whorl; sterile and fertile whorls usually similar; twice or thrice furcate; primary ray less than half the length of the whole branchlet. Rays at the first furcation 6, at the second 4, at the third 2–3. Ultimate rays usually 2-celled with a narrow mucro-like terminal cell perched on the rounded apex of the lower cell. Dactyls elongated, unequal. Oogonia and antheridia produced at all the forkings. Oogonia 500–550 μ long, 400–425 μ broad. Oospore dark, 300–350 μ long, 250–300 μ broad; ridges 7. Membrane light yellow brown reticulate. Antheridium 200–250 μ in diameter.

Locality.—(1) Ratnagiri (Parandekar), Feb. 1938. (2) Chiplun (Agharkar), 1914.

This species is highly variable and the specimens from the widely separated localities differ not only in their general habit and build but also in the number of branchlets, number of furcations, the length of the dactyls and the decorations of the oospore membranes. The mucronate character of the dactyls is constant but is a feature by no means confined to this species.

3. *Nitella tenuissima* Kütz. var. *byssoides* Braun.—A. Braun, *Charac. Ind. Orient.* in Hook., *Journ. Bot.*, Vol. I, London, 1849, p. 294; Braun and Nordstedt, *op. cit.*, 1882, p. 64; Groves, *Journ. Linn. Soc. Bot.*, 1924, Vol. XLVI, No. 310, pp. 359–76.

Stem slender, 320–380 μ thick; internodes longer than the branchlets. Branchlets usually 6, twice furcate, ultimate rays 3–4, 2-celled, end-cell elongated, acuminate. Gametangia produced at the second furcation. Oogonia solitary, 340–350 μ long, 275–285 μ broad; coronula 20–22 μ high. Oospore 225–235 μ long, 210–215 μ broad; ridges 7–8, low. Antheridium small, 170–175 μ in diameter.

Locality.—Pond, Alibag (Colaba Dist.), Aug. 1935.

This small and slender variety which has branchlets only twice furcate as a rule and with a much smaller fruit is recorded here for the first time from the Bombay Province and is the second record of it from India. It was first recorded from the Coromandel Coast in 1826. The present plant grew along with *Nitella furcata* Ag. and *Spirogyra bimorphis* Dixit.

N. tenuissima is allied to *N. batrachosperma* Br. It mainly differs by usually not fruiting at the first forking, the oospore having less prominent ridges, the internodes being longer and the membrane being reticulate. *N. batrachosperma* has a granulate membrane.

4. *Nitella furcata* Ag.—Braun and Nordstedt, *op. cit.*, 1882, p. 73; A. Braun, in Hook., *op. cit.*, 1849, p. 292; Roxburgh, *Flor. Ind.*, Vol. III, 1832, p. 564.

Monœcious. Stem stout, 800–1,000 μ thick; internodes once to twice the length of the branchlets. Branchlets 6, 3–4 times furcate. Primary rays about half the length of the whole branchlet, secondary rays up to 6; tertiary rays 3–4; dactyls shortened and divergent, ultimate rays 2-celled; apex acuminate. Oogonia clustered, 500–550 μ long, 300–350 μ broad; convolutions 8–9. Cells of the upper tier of the coronula elongated to fine points, 80 μ long, sometimes unequally elongated and divergent. Oospore dark, 275–300 μ long, 200–225 μ broad. Membrane reticulate. Antheridium 250–275 μ in diameter, produced at the upper furcations.

Locality.—Pond, Alibag, Aug. 1935.

This species is recorded from Coromandel Coast, Pegu, Nicobar Islands, Ceylon and Philippine Islands. *N. japonica* Allen and *N. guineensis* Kütz. from W. Africa are considered related species.

5. *Nitella dualis* Nordst.—(=*N. superba* Pal. Pal, " Burmese Charophyta, *Journ. Linn. Soc. Bot.*, 1932, Vol. XLIV, No. 327, p. 67, Pl. 8.)

Dicœcious. Male plant.—Stem 400–425 μ thick; internodes 1–2 times the length of the branchlets. Entire plant enveloped in mucus. Branchlets 6 in a whorl; 2–3 times furcate. Primary rays $\frac{2}{5}$ to $\frac{1}{2}$ length of branchlet; secondary rays 6; tertiary 3–6, of which one or more simple; quaternary 3–6. Dactyls very long, 2-celled; end-cell allantoid with a distinct mucronate tip. Antheridia orange coloured, at the first, second or third furcations; 350–400 μ in diameter, on a small stalk cell.

Female plant.—Stem 350–375 μ in diameter; internodes 1–2 times the length of the branchlets. Entire plant enveloped in mucus. Branchlets 6 in a whorl; 1–3 times furcate. Fertile shoots smaller and shorter than the sterile ones. Oogonia solitary, usually at second furcation; 300–330 μ long (incl. coronula), 220–240 μ broad; coronula 40 μ high; convolutions 8.

The specimens measured 3–6 cm. in length, appeared olive green and were densely covered with mucus.

Locality.—In running water on sands in bed of the river Saravati above Jog Falls; August, 1938. Species of *Spirogyra*, *Desmids* and *Mougeotia jogensis* Iyengar were associated with this plant.

N. dualis Nordst. comes very near *N. myriotricha* Kütz. though differs in the size of the oogonia and the number of cells in dactyls. The species referred to by Groves (1924) as " *Nitella* sp., *N. myriotricha* Kütz. prox. " collected by Burkill at Amboli in Western Ghats, Bombay Presidency, also resembles the present plant. It also agrees very well with *Nitella superba* Pal and to all appearance *N. superba* should be considered a form of *N. dualis* Nordst. at the most. *N. dualis* has also some superficial resemblance with

N. dispersa Br. but the absence of mucus, the sessile antheridia and the absence of the dissimilar shoots in the latter are sufficient characters to distinguish it from the former species.

6. *Nitella hyalina* Ag.—Braun and Nordstedt, *op. cit.*, 1882, p. 78; Groves and Bullock-Webster, *British Charophyta*, 1920, Vol. I, Pl. XVI.

Monœcious. Stem 375–425 μ thick; internodes 2–4 times the length of the branchlets. Branchlets in each whorl of two kinds, usually 8 primary branchlets and about as many shorter and simpler branchlets produced in each of two series above and below the primary branchlets. Primary branchlets 2–3 times furcate; secondary rays 7–10; tertiary 4–7 with quarternary rays; ultimate rays two celled. Lower series of accessory branchlets once or twice furcate; rays 4–6; the upper series once furcate. Gametangia at all furcations. Oogonia solitary, 400–425 μ long, 250–300 μ broad, convolutions 7–8. Oospore brown, 265–275 μ long, 190–200 μ broad, ridges 6, membrane granulate. Antheridium 250–260 μ in diameter.

Locality.—Ajawa Tank, Baroda, April, 1938. (2) Moola-Mootha River, Poona, April, 1935. (3) Kolhapur (Parandekar), Jan., 1939. (4) Watrak River (L.J. Sedgwick), 1915. (5) Kathiawar (Sir G. Watt). (6) Chiplun (Agharkar), 1913.

At Ajawa Tank at Baroda the species occurred in vast quantities at the bottom of the tank as well as in the cracks and crevices of the dam. The specimens varied from 3–20 cm. in length. In the smaller specimens the branchlets were close set. The Poona plants were longish with the branchlets far apart as in the normal plants. In all cases the young fruiting parts were enveloped in mucus while the older parts were lime incrusted.

II. CHARA

7. *Chara succincta* Br. Braun and Nordstedt, *op. cit.*, 1882, p. 114, Taf. VII, Fig. 200–202; Dixit, "Some Charophyta from Salsette," *Journ. Ind. Bot. Soc.*, Vol. X, No. 3, 1931, pp. 205–208.

This species has been described by the author in this *Journal* in 1931. This is the second record of the species and its extension to the Indian desert is noteworthy.

Locality.—Lyaree River, Karachi, March, 1938.

The river bed where the plants were found consisted of coarse sand and the water was appreciably warm in the afternoon when the plants were collected. A species of *Pithophora* was epiphytic.

8. *Chara nuda* Pal. Pal, *op. cit.*, 1932, p. 81, Pl. 15.

Forma *kolhapurensis* form. nov.

Monœcious. Stem slender; 325–350 μ thick, entirely ecorticate. Stipulodes in a single circle, usually rudimentary but occasionally distinctly developed. Branchlets incurved, ecorticate, 11 at a whorl, and of 5 segments, terminating in a short, narrow and blunt cell. Bracts and bracteoles rudimentary. Gametangia at the

lower nodes. Oogonia solitary, 800–860 μ long, 425–450 μ broad; coronula 130 μ high, 250 μ broad; convolutions 10–12. Oospore black, 500 μ long, 280 μ broad. Antheridium 325–330 μ in diameter.

Locality.—Kolhapur (S. A. Parandekar), October, 1938.

A medium sized plant heavily lime incrusted.

This form does not quite agree with the type nor does it agree with *Chara pashanii* Dixit described in this *Journal* in 1935. It agrees with *C. nuda* Pal in having rudimentary stipulodes and in the coronula being more or less spreading, the oogonia being solitary and the larger size of its sex-organs. It appears to be rather intermediate form between the two species. This is the second record of this plant and its geographic extension to the south-west is interesting.

9. *Chara corallina* Willd. A. Braun, *op. cit.*, in Hook., p. 294; Braun and Nordstedt, *op. cit.*, 1882, p. 108.

This species which was briefly described in the second paper is recorded here from two new localities in the Province.

Locality.—Pond, Goregaon, Bombay, Sept., 1937 (R. Menon).
(2) Kolhapur (Parandekar).

10. *Chara gymnopitys* Br. Braun and Nordstedt, *op. cit.*, 1882, p. 124.

Monœcious. Stem corticate, 550–580 μ thick. Cortex diplostichous, primary series more prominent than the secondary series. Spine cells short or long and conspicuously developed. Stipulodes long, acute, in a single circle. Branchlets 10–12, spreading, of 4–5 segments, ecorticate. Bract cells 4–6, long, slender, acuminate. Gametangia at the lower three nodes. Oogonia 650–800 μ long, 400–500 μ broad, convolutions 10–11. Oospore black, 450–500 μ long, 280–360 μ broad. Antheridium 400–415 μ in diameter.

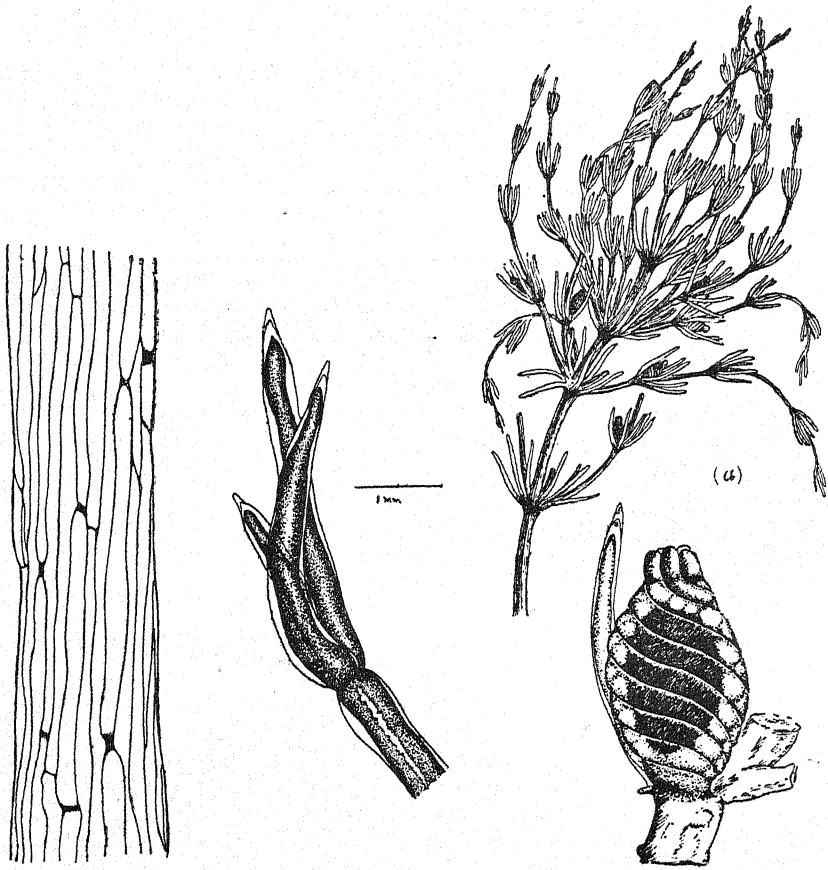
Locality.—In stony parts of the bed of the river Saravati above Jog Falls in a fairly strong current; August, 1938.

This species which was noted in the second paper is now recorded here from the southern-most point of the Bombay Province. The Jog Falls specimens were sterile and had exceptionally long and slender stipulodes.

The species differs from *C. flaccida* Br. by the black colour of its oospore. It also appears that this species is highly variable in the measurements and the number of its parts. *C. Benthami* Br. regarded by Groves as a variety of this species was separated by Braun by the comparative number of stipulodes and branchlets. *C. gymnopitys* having double as many stipulodes as branchlets was placed among the Bistipulatæ. Mr. G. O. Allen, however, considers both of them as the extreme forms of the same species.

11. *Chara Hatei* sp. nov.

Plant minute, 2–3 cm. long, trailing on the soil. Monœcious. Stem slender, 300–400 μ thick; stem-cortex triplostichous (rows of



(*b*) Stem Cortex

(*c*) Tip of a branchlet

(*d*) Oogonium

Chara Hatei sp. nov.

(*a*) Nodes with some branchlets removed showing the general appearance of the plant. × *c.* 8. (*b*) Stem-cortex. (*c*) Tip of a branchlet. (*d*) Oogonium × *c.* 60.

cortical cells 3 times as many as the branchlets); the primary series rather larger than the secondary; a few lower internodes partly ecorticate. Spine cells minute, almost rudimentary; stipulodes in a single circle (haplostephanous), long, pointed. Branchlets 10; longer than the internodes, segments usually five, ecorticate, except the lowest but one which is comparatively short and often corticate. Bracts 5, long, $\frac{1}{4}$–$\frac{3}{4}$ the length of the segment, 65–75 μ broad. Gametangia at the lower two nodes. Oogonia 450–500 μ long, 300–315 μ broad; coronula 116 μ broad, 67 μ high. Spiral cells showing about 9 convolutions. Oospore black, 325 μ long, 180 μ broad.

Locality.—Sub-aerial, on boggy soil under a thick cover of a monsoon forest at Bhivandi on the way to Vajareshwari springs, near Thana, August, 1937.

The plants formed a carpet on humus soil and were mixed with species of *Lyngbya*, *Microcoleus* and *Oedogonium*. It does not seem to take up lime at all.

There is only one haplostephanous triplostichous *Chara* hitherto known to science, *viz.*, *Chara scoparia* Braun, which has the branchlets entirely ecorticate and in the typical form the spine-cells developed.*

12. *Chara globularis* Thuillier var. *fragilis* (1799)—(= *Chara fragilis* Desv., 1810). Braun and Nordstedt, *op. cit.*, 1882, p. 181; Groves, *op. cit.*, 1880, p. 101, t. 207, f. 1.

Monœcious. Stem slender, 500–750 μ thick; internodes as long as or longer than branchlets; cortex regular, triplostichous; cells of secondary series as broad as the primary ones, *c.* 48 μ. Spine cells rudimentary. Stipulodes in a double circle, rudimentary. Branchlets 7–8, incurved, tapering to a point at the apex, upper 1–3 nodes ecorticate, lowest segment moderately long, cortical cells of the branchlets twice as numerous as the bract cells. Bracts 1–2, developed. Bracteoles as long as or $\frac{2}{3}$ the length of the fruit, sharp. Gametangia produced at three lower nodes. Oogonia 800–850 μ long, 500–550 μ broad. Oospore black, ellipsoidal, 545–555 μ long, 350–355 μ broad, ridges 12. Antheridium 300 μ in diameter.

Locality.—Moola River, Aundh near Poona, Dec., 1936. (2) Kolhapur (Parandekar). (3) Bombay (Major Hobson). (4) River, Poona (G. M. Woodrow, 1895).

The Aundh plant is rather small, 10–15 cm. long, lime covered, and grew in a muddy flow of the river. A species of *Spirogyra* was epiphytic on it.

13. *Chara brachypus* Braun. A. Braun, in Hook., *op. cit.*, p. 296; Braun and Nordstedt, *op. cit.*, 1882, p. 185.

Monœcious. Stem 600–700 μ thick; internodes as long as or longer than the branchlets. Spine cells minute, solitary, acute. Stipulodes in a double circle, elongated, acute; cortex triplostichous, cells of both the series similar. Branchlets corticate, 9–11 in a whorl, incurved, segments 8, rarely upper segments ecorticate, lowest segment short. The cortical cells of the branchlet are about three times as numerous as the bract cells. Bract cells 3–6, not well developed, unequal. Gametangia at the three lower nodes. Oogonia 840–860 μ long, 550–580 μ broad, convolutions 12–13. Oospore

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* Named after Prof. V. N. Hate of Wilson College, Bombay, who was the Indian pioneer to study these plants.

350–400 μ long, 280–300 μ broad. Antheridium 300–350 μ in diameter.

Locality.—Pond, Alibag, August, 1935. (2) Kolhapur (Parandekar). (3) Beyt Dwarka, 1912. (4) Chiplun (Agharkar, 1913).

This species often becomes brittle by excessive absorption and deposition of lime.

14. *Chara zeylanica* Willd. (1805).—(= *Chara gymnopus* Br.). Braun and Nordstedt, *op. cit.*, 1882, p. 189.

Monœcious. Stem stout, 700–850 μ thick ; cortex triplostichous ; internodes longer than the branchlets. Stipulodes in two series, elongated, acute. Spine cells long, solitary, acute. Branchlets corticate, 9–11 in a whorl, tapering, spreading out or straight ; segments 6–9, lowest segment usually very short, *ecorticate*, upper segments 1–3 often ecorticate. Bract cells about 9 ; bracteoles longer than the fruit. Gametangia produced from second to upper four nodes. Oogonia ovate, 800–1,000 μ long, 400–500 μ broad; coronula 85 μ high, 180 μ broad, blunt, divergent ; convolutions 12–14. Oospore brown or black, 550–600 μ long, 325–350 μ broad. Antheridium quadriscutate, 300 μ in diameter.

Locality.—Bhayender (Salsette), December, 1935. (2) Warasia Tank, Baroda, April, 1938. (3) Lyaree River, Karachi, March, 1938.

This species is a highly variable one with numerous forms. The lime deposit on it is either in rings or uniformly laid all over. A few branches on one of the Baroda specimens were found to have all the branchlets ecorticate. Braun has recorded such a form *Viellardi* from New Caledonia and figured in Taf. VII, Figs. 272–3. This is the only species so far known which has four lozenge-shaped antheridial shields instead of the usual eight triangular ones. Species of *Lyngbya*, *Spirogyra* and *Oedogonium* are a few of the epiphytes found on this plant.

The author expresses his grateful thanks to Mr. G. O. Allen for his most valuable help throughout the preparation of this paper. He has also to thank Prof. S. A. Parandekar of the Rajaram College, Kolhapur, for presenting him with the specimens collected by him.

Summary

The present paper is in continuation of the past two papers published by the author in this *Journal* in 1931 and 1935. So far, sixteen species of charophytes were recorded from the Bombay Presidency. In this paper four additional species, *viz.*, *Nitella opaca* Ag., *Nitella tenuissima* Kütz. var. *byssoides* Br., *Nitella dualis* Nordst. and *Chara Hatei* sp. nov., have been described. Short descriptions and fresh localities of some of the species recorded in the past have been added.

BIBLIOGRAPHY

1. Allen, G. O. (1936) .. " Charophyte notes from Bareilly," *Journ. Ind. Bot. Soc.*, **15**, No. 1.
   ———— (1933) .. " Charophyte notes from Agra, U.P., " *Ibid.*, **12**, No. 1.
2. Dixit, S. C. (1931) .. " Some Charophytes from Salsette," *Journ. Ind. Bot. Soc.*, **10**, No. 3.
   ———— (1935) .. " The Charophytes of the Bombay Presidency," *Ibid.*, **14**, No. 3.
3. Drew, K. M. (1926) .. " The Leaf of *Nitella opaca*," *Ann. Bot.*, **40**, pp. 321–48.
4. Ernst, A. (1904) .. " Die Stipularblatter Von *Nitella hyalina* (D.C.) Ag., " *Beitrage Zür Kenntniss der schweizerischen Characeen*, Zurich,
5. Groves, J. (1935) .. " The primary Divisions of the Genus *Nitella*," *The Journ. of Bot., London*, Feb.
   ———— (1931) .. " On the antheridium of *Chara zeylanica* Willd.," *Ibid.*, April.
   ———— (1922) .. " On Charophyta collected by Mr. Thomas Bates Blow, F.L.S., in Ceylon," *Journ. Linn. Soc. Bot.*, **46**.
   ———— (1928) .. " On Charophyta collected by Mr. T. B. Blow from Madagascar," *Ibid.*, **48**.
   ———— (1924) .. " Notes on Indian Charophyta," *Ibid.*, **46**.
6. Groves, J., and Allen, G. O. (1935) " A Review of the Queensland Charophyta," *Proc. Roy. Soc. Queensland*, May, **46**, No. 4.
7. Groves, H., and Groves, J. .. " On Characeæ collected by Mr. Blow, F.L.S., in the West Indies," *Journ. Linn. Soc.*, **33**.
8. Hate, V. N. (1909) .. " Two species of *Chara* from the Bombay Island," *Journ. Bom. Nat. Hist. Soc.*, Nov.
9. Kundu, B. C. (1938) .. " A New Species of Polyarthrodactylous *Nitella* with a review of the allied species," *Journ. Ind. Bot. Soc.*, **16**, No. 5.
10. Pal, B. P. (1932) .. " Burmese Charophyta," *Journ. Linn. Soc. Bot.*, **49**.

THE ANATOMY OF *SPINIFEX SQUARROSUS* LINN. WITH SPECIAL REFERENCE TO THE MORPHOLOGY OF THE LEAF-BLADE

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AMONG the psammophilous halophytes, the Gramineæ is represented by *Spinifex squarrosus* Linn. The plant is a glaucous shrub with creeping stem, rooting at the nodes. It occurs on the sea-shores, covering large patches of sand and converting them into sand-dunes.

ANATOMY OF THE STEM

The epigeous parts of the stem are pale green and are covered at the nodes by the sheathing leaf-bases. The epidermis of the stem resembles that of the grasses. The cuticle is well developed and is coated with wax (Fig. 1). Depressed stomata occur in longitudinal rows. The epidermis is supported at intervals by groups of stereome bands with apposed vascular bundles. The larger bundles are supported on both faces by fibrous strands, thus forming composite girders. The bundles are invested by a sheath of chlorenchyma (Fig. 1). The cells occurring below the stomata are thin-walled and are somewhat radially elongated. The sub-epidermal ring of vascular bundles is followed by a zone of 5–6 layers of large, vertically elongated, mostly clear cells with minutely pitted walls. Crystals of oxalate of lime occur as irregular pieces. Next comes a strongly lignified ring of 7–8 layers of sclerenchyma. Within this ring, the ground tissue is traversed by scattered vascular bundles of the grass type. In the young stem chloroplasts occur in the ground tissue ; in the mature parts, some of the cells have pitted and lignified walls, while others contain large, compound starch grains.

The base of each internode is soft and constitutes the intercalary meristematic zone. As the silica impregnation is feeble the sinuate walls of the epidermal cells are clearly visible. The stomata are few and occur at rare intervals. The subepidermal girders and the ring of sclerenchyma of the mature stem are not developed. As noted by Haberlandt (1914) and Goebel (1922) in the Cyperaceæ and the Gramineæ, the meristematic intercalary zone is supported by the overlapping leaf-sheaths, in which the mechanical system is well developed.

ANATOMY OF THE ROOT

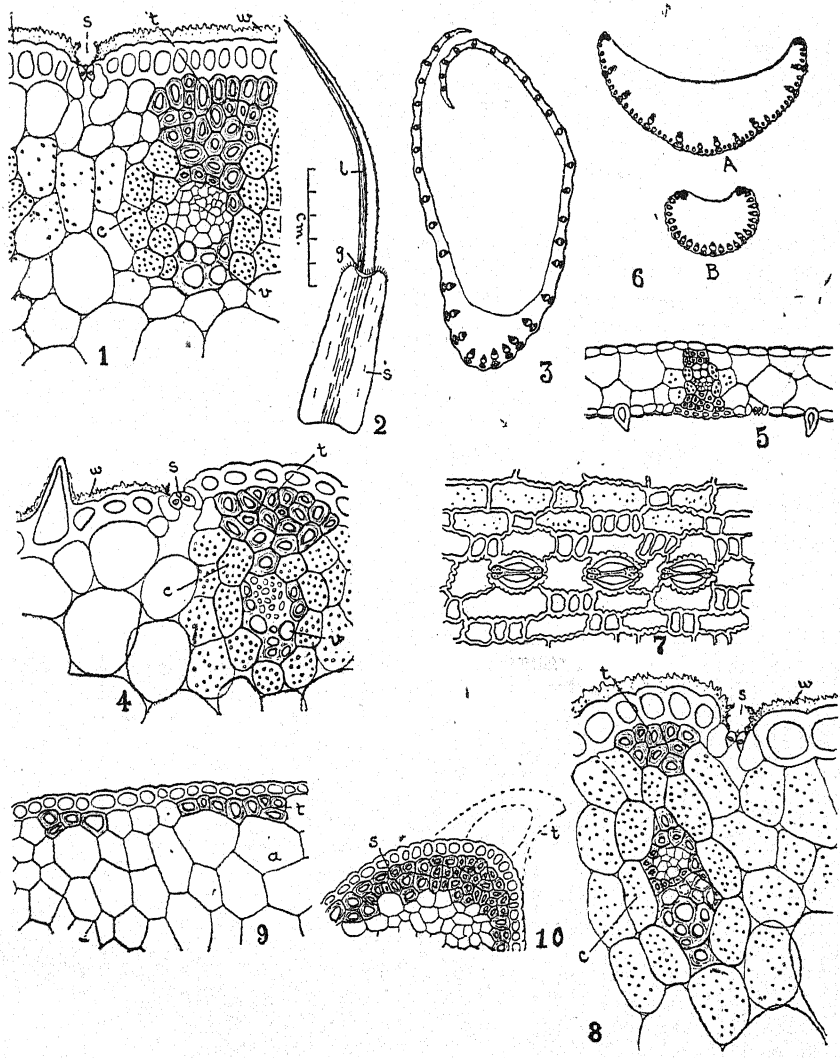
The cortex is composed of polygonal cells with pitted walls. The endodermis and the pericycle are thick-walled and lignified. The stele is polyarch. The pith is composed of thin-walled cells with pitted walls. Strongly lignified, short, fibre-like cells occur in the pith.

Anatomy of the Leaf

The leaf of *Spinifex squarrosus* consists of a leaf-sheath and a leaf-blade or limb with a ligule represented by a ridge of hairs (Fig. 2). The tough sheaths of successive leaves enfold one another in an equitant manner, surrounding and supporting the intercalary meristematic zones.

(*a*) *Leaf-sheath.*—The sheath consists of a thick midrib-like region and a thin flat wing on either side (Figs. 2, 3). The thick median region is mainly composed of a number of large, clear cells and an open arc of vascular bundles towards the abaxial side (Fig. 3). The abaxial or outer surface is hairy and shows the characteristic ridges and grooves due to the occurrence of subepidermal fibrous strands at intervals. The epidermis covering the ridges appears in surface view to be composed of narrow elongated cells with thick, pitted and lignified walls, while that of the groove is composed of broad cells with comparatively thin walls. The unicellular trichomes and the stomata occur in longitudinal rows and are confined to the grooves. In the flat wing-like part of the sheath, the stomata occur on both surfaces being more numerous on the abaxial side, while in the midrib region they are entirely confined to the abaxial side. Wax covers the outer surface of the grooves, but is absent on the ridges (Fig. 4). In the midrib region, the epidermis on the abaxial side is followed at intervals by strands of stereome with apposed vascular bundles arranged in an arc open above (Fig. 3). The larger bundles are invested by a fibrous sheath. Each bundle is surrounded by a sheath of chlorenchyma. The adaxial or inner epidermis of the midrib region is supported by groups of sclerenchyma. The midrib region is mainly composed of large, clear cells forming an aqueous tissue. Here and there a few simple and clustered crystals of oxalate of lime occur. The thin wing-like part of the sheath is composed of vascular bundles, each encircled by a sheath of chlorenchyma, and large clear cells (Fig. 5). The fibrous strands occur on both surfaces of the vascular bundles and extend from epidermis to epidermis, forming the typical I-girders.

(*b*) *Leaf-blade.*—Cooke (1904), Ranga Achariar[1] (1921), Blatter (1935) and others have described the leaf-blade of *Spinifex squarrosus* as thick, rigid, tapering, concavo-convex with scaberulous margins. Schimper (1903, p. 182) remarks that the plants on the sandy seashore "have the important faculty of again growing out of the sand, after having been covered by it". The sharp-pointed rigid leaves of the plant under consideration enable it in making its way easily out of the sand when it gets buried. An examination of the 'blade', *i.e.*, the limb, shows that it is not like the normal flat blade of the grasses. It appears to be merely a continuation of the thick, midrib-like region of the sheath, the flat, wing-like part on either side not extending into the limb (Fig. 2). In cross-section, the major part of the almost solid limb presents a crescentic outline with a groove on the upper side as is the case with petioles in general. It is composed mainly of a number of large clear cells and an arc of



Spinifex squarrosus Linn. Fig. 1. T.S. stem : *s*, stoma ; *t*, stereome ; *v*, vascular bundle ; *c*, chlorenchyma ; *w*, waxy coating. (× 500). Fig. 2. Leaf : *s*, leaf-sheath ; *g*, ligule ; *l*, limb. Fig. 3. T.S. leaf-sheath with the adaxial side towards the top of the page. Xylem is represented black, phlœm white and fibres dotted. (× 16). Fig. 4. T.S. leaf-sheath, abaxial side : *s*, stoma ; *t*, stereome ; *v*, vascular bundle ; *c*, chlorenchyma. (× 500). Fig. 5. T.S. leaf-sheath, wing portion. (× 240). Fig. 6. T.S. limb with the adaxial surface towards the top of the page. Xylem is represented black, phlœm white and fibres dotted. *A*, section lower down and *B*, towards the apex of the limb. (× 16). Fig. 7. Epidermis of the abaxial side of the limb. (× 500). Fig. 8.—T.S. limb, abaxial side : *s*, stoma ; *t*, stereome ; *c*, chlorenchyma ; *w*, waxy coating. (× 500). Fig. 9.—T.S. limb, adaxial side : *t*, sclerenchyma ; *a*, aqueous tissue. (× 240). Fig. 10.—T.S. limb, marginal part : *s*, stereome ; *t*, marginal tooth. (× 240).

vascular bundles whose concavity is adaxial, recalling the arrangement in many petioles and midribs. There is no central median bundle forming a midrib but the whole of the ' blade ' is traversed on the abaxial side, by a row of vascular bundles, smaller bundles being spaced alternately between the larger ones (Fig. 6). The internal structure of the ' blade ' also resembles that of the midrib region of the basal sheath. The cuticle is well developed and has a heavy coating of wax. The abaxial or lower side shows ridges and grooves due to the presence of subepidermal girders. The epidermis resembles that of the midrib region of the sheath (Fig. 7). The stomata occur in the grooves and are entirely confined to the abaxial side. They are more depressed than in the sheath (Fig. 8). The epidermis on the abaxial side is supported by groups of stereome with apposed vascular bundles as in the sheath. The epidermis on the adaxial side is strengthened not by ordinary girders but by broad plates of sclerenchyma (Fig. 9). Each bundle is encircled by a ring of chlorenchyma composed of large oval cells. The spaces between the vascular bundles are occupied by thin-walled parenchyma holding a few chloroplasts and starch grains. The major portion of the limb is filled with large clear polygonal cells, forming an aqueous tissue. The cells have stiff walls and there are no intercellular spaces. Towards the margin of the ' blade ', some of these cells have minutely pitted and lignified walls. Higher up the ' blade ', more and more of these clear cells get pitted and lignified, till towards the extreme end all the cells have lignified walls, thus forming the hard, sharp-pointed apex of the leaf. The margin is strengthened by a thick band of stereome (Fig. 10). The latter perhaps is the only remnant of the suppressed leaf-blade.

A typical grass leaf is described as consisting of a sheathing leaf-base and a leaf-blade or limb with a ligule at the junction of the two. De Candolle (1827) was the first to put forward the theory, known as the 'Phyllode Theory ', that the typical monocotyledonous leaf corresponds to the petiole with a sheathing leaf-base. Arber (1918, 1922) has elaborated the phyllode theory and has shown by anatomical evidence that the leaves of monocotyledons are equivalent to the leaf-base and the petiole of the dicotyledons, the lamina being unrepresented. The same writer (1923, p. 375) is further of opinion that in the leaf of the Gramineæ "despite the minor modifications to which it is liable, the basal sheath in all cases is equivalent to the same region in the dicotyledon, while the limb corresponds to the petiole of the dicotyledon the lamina being absent". A study of what is called the ' leaf-blade ' in *Spinifex squarrosus* shows that it differs from that of the typical grasses in the absence of the flat lamina portion and is represented by what appears to be the thick midrib region alone. From the point of view of the phyllode theory it may be interpreted as a petiolar phyllode in which the lamina is represented by the midrib alone. The crescentic outline of the ' blade ' in cross-section, with a groove on the upper surface, and the arrangement of the vascular bundles in the form of an open arc whose concavity is adaxial, recalls the

structure of many petioles and midribs. The anatomy of the 'blade' also supports the view that it is mainly composed of the midrib region. A close resemblance in structure can be traced between the 'blade' of *Spinifex squarrosus* and the prominent keels or midrib regions of the linear leaves of grasses like: *Sorghum vulgare* Pers., *Coix Lachryma-Jobi* Linn., *Zea Mays* Linn., *Saccharum officinarum* Linn., *Cymbopogon citratus* Stapf., *Arundo Donax* Linn., etc. A feature showing that the 'blade' is not equivalent to the lamina of the grasses is the placing of the stomata. Duval-Jouve (1875), Lewton-Brain (1904) and others have observed that in xerophytic and maritime grasses the stomata are entirely or mostly confined to the upper surface of the leaf which is the protected side. In the grass under consideration, the stomata are entirely confined to the lower side of the 'blade'. The normal position of the stomata on the midrib region of the grasses like *Sorghum vulgare*, etc., mentioned previously is only on the lower surface. This again shows the midrib nature of the 'blade' of *Spinifex squarrosus*. Another feature which invites comparison with the thick midrib regions of the grasses like *Sorghum vulgare*, etc., is the unequal disposition of the mechanical system of the two surfaces of the limb. The adaxial or upper epidermis is not strengthened by ordinary girders but by broad subepidermal plates of sclerenchyma (Fig. 9). In *Saccharum*, *Zea*, etc., Haberlandt (1914) has shown that this form of mechanical system is characteristic of leaf-midribs. Suppression of the wing portion of the leaf is recorded in several cases. Thus among the dicotyledons Arber (1925) has noted some cases of reduced leaves in which the lamina is represented by the midrib alone. Among the Gramineæ, Duval-Jouve (1875, p. 301) has noted instances of reduced leaves in *Andropogon lanigerum* and *Imperata cylindrica* where the limb "is reduced to a thick midrib nearly devoid of lateral green expansions". Volkens (1887, p. 184) has mentioned instances of reduced leaves in *Andropogon hirtus* L. and *Elionorus hirsutus* Munro, where "the flat portion of the lamina is reduced to a small edge which is attached on either side to the thick midrib". Lewton-Brain (1904, p. 319–20) has also noted cases of xerophytic grasses where: "the midrib forms the greater part of the leaf...and the whole of the lateral parts of the leaf have become mere appendages of the midrib". Except for the band of marginal stereome, which perhaps is the only remnant of the suppressed leaf-blade, the lamina in *Spinifex squarrosus* seems to be totally suppressed and only the central midrib region is left. The latter because of its almost semiterete form effectively reduces the transpiring surface.

SUMMARY

The anatomy of the stem, root and leaf of *Spinifex squarrosus* is described.

An examination of the leaf shows that the 'leaf-blade' region is not like the typical linear leaf of the grasses, but is a reduced structure and is equivalent to the midrib region alone.

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REFERENCES

Arber, A. (1918) .. "The Phyllode Theory of the Monocotyledonous Leaf, with Special Reference to Anatomical Evidence." *Ann. Bot.*, **32**, 465–501.

——— (1922) .. "On the Nature of the 'Blade' in Certain Monocotyledonous Leaves." *Ibid.*, **36**, 329–51.

——— (1923) .. "Leaves of the Gramineæ," *Bot. Gaz.*, **76**, 374–88.

——— (1925) .. "Monocotyledons, a Morphological Study," Univ. Press, Camb., 99–100.

Blatter, E., and McCann, C. (1935) "The Bombay Grasses," *Imp. Council of Agric. Res. Sc. Mono., Delhi*, No. 5, 122–23.

Candolle, A. P. de (1827) .. *Organographie vegetale*, 2 Vols., Paris.

Cooke, Th. (1904) .. *The Flora of the Presidency of Bombay*, Vol. II, 913.

Duval-Jouve, J. (1875) .. "Histotaxie des feuilles de Graminées," *Ann. Sci. Nat. Ser.* 6, Bot., **1**, 294–371.

Goebel, K. (1922) .. *Organography of Plants*, Engl. Ed., 2, 298, Oxford.

Haberlandt, G. (1914) .. *Physiological Plant Anatomy*, Eng. Ed., 102, 179, 183, Lond.

Lewton-Brain, L. (1904) .. "On the Anatomy of the Leaves of British Grasses," *Trans. Linn. Soc. Lond.* Ser. 2, Bot., **6**, 315–59.

Ranga Achariar, K. (1921) *A Handbook of Some Indian Grasses*, 38, 104, 105, Govt. Press, Madras.

Schimper, A. F. W. (1903) .. *Plant Geography upon a Physiological Basis*, Engl. Ed., 180, Oxford.

Volkens, G. (1887) .. *Die Flora der Aegyptisch-Arabischen Wüste*, 146–51, Berlin.

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Figure No. 3 in page **117** should be placed in page **118** in place of **Figure No. 4** and *vice versa.*

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